ARS-BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

Northwest Watershed Research Center
Western Region
Agricultural Research Service
U. S. Department of Agriculture

INTERIM REPORT NO. 8

Cooperative Agreement No. 12-14-5001-6028

For Period January 1, 1977 to December 31, 1977

TO

Denver Service Center
Bureau of Land Management
U. S. Department of the Interior
Denver, Colorado

APRIL 1978

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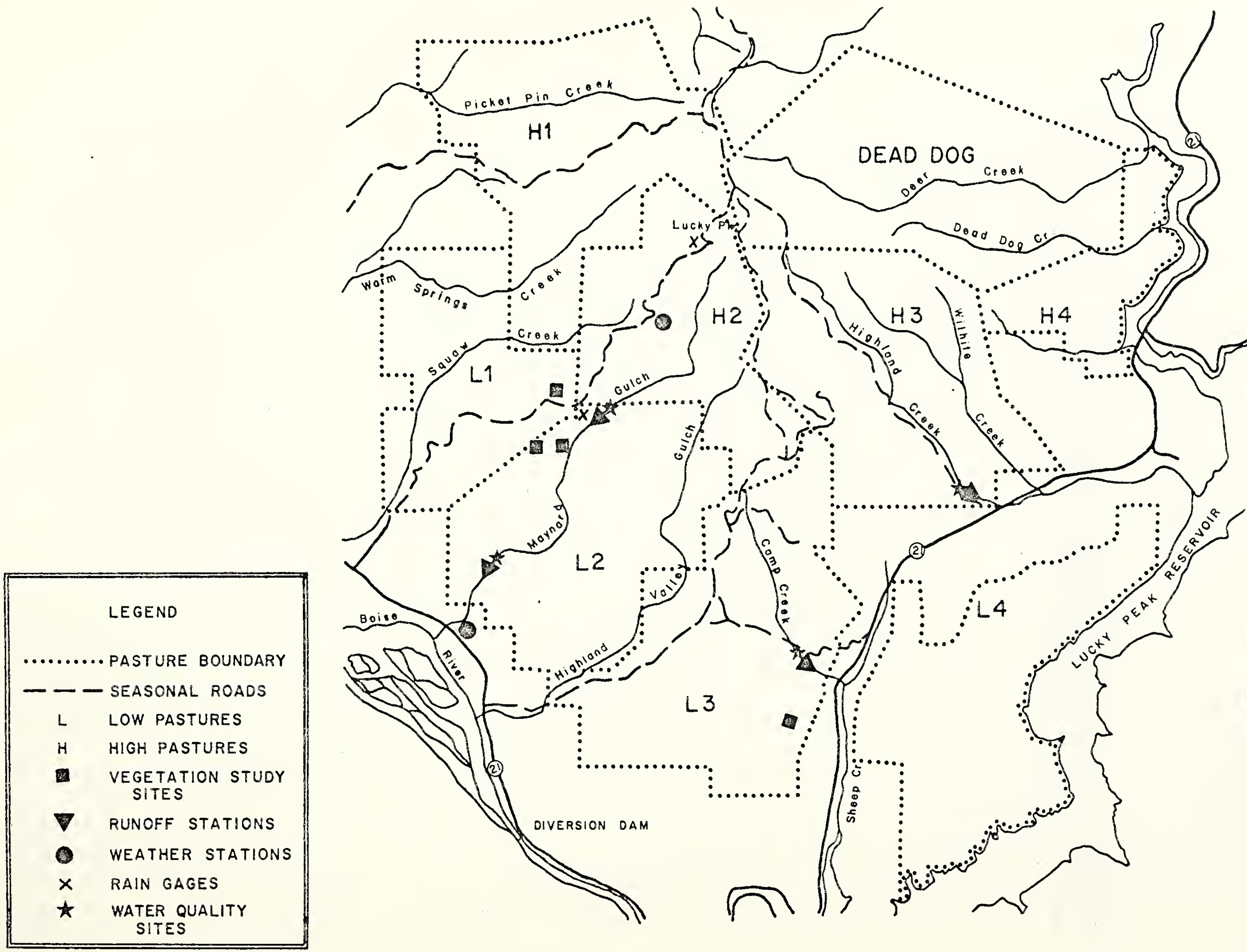
NOTE

Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.



Introduction Figure 1.--Boise Front locations.

INTRODUCTION

Cooperative watershed research between the Agricultural Research Service, U. S. Department of Agriculture, and the Bureau of Land Management, U. S. Department of the Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1960, which is a part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results on the Reynolds Creek Watershed and supporting studies on the Boise Front from January 1 through December 31, 1977. Data collection, processing, analysis, and reporting are according to the FY 1977 work plan. Progress reports are given by the individual sections of the work plan. A copy of the FY 1977 work plan precedes the progress reports.

Supporting information and data are presented in Northwest Watershed Research Center Annual Reports for 1972 and prior years, and in Interim Report Nos. 1, 2, 3, 4, 5, 6, and 7 for the ARS-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 14-11-0001-4162(N).

On the Boise Front, a partial year of study on the Lucky Peak Resource Management Unit has been completed. The Unit, consisting of 15,740 acres, is divided into eight pastures on which a 4-year rest-rotation grazing system has been established for April through October livestock grazing. The unit is also the winter browse area for the largest deer herd in Idaho. The ARS research objectives are to determine the effects of the rest-rotation grazing and deer management system on runoff and water yield, sediment yield, vegetation composition and cover, and water quality. Results from this study will be used to compare Boise Front watershed data with watershed data from the Reynolds Creek Watershed, giving a measure of Reynolds Creek data applicability. Research locations are shown in Introduction Figure 1.

The 5-year data base of water quality parameters and associated hydrologic parameters on the Reynolds Creek Watershed is being supplemented with a cooperative project with the University of Idaho. This study is investigating the effects of livestock winter feeding on water quality of a rangeland stream. Primary focus is on evaluating runoff water quality control practices for this phase of the rangeland enterprise.

Weather - 1977 Water Year

A detailed report on the 1976-77 drought is presented in Appendix I. Highlights of this report are as follows:

Precipitation on the Reynolds Creek watershed varied from 7.32 to 21.12 inches and was about 55 percent of the 1961-1976 average. Average or above rainfall in May and June improved forage production at higher elevations to above average levels. Rangeland forage production at lower elevations was very low as the early months were very dry. Soil water levels were at average or above levels from late May through the summer.

Total water yield at the Reynolds Creek outlet was 11 percent of previous years' average. Snowpack accumulation on April 1, 1977, was only 38 percent of average water content. Most snow was melted by May 1 compared to late June in normal years. Water supply available to valley irrigators measured at Tollgate was only 13 percent of previous years average.

Groundwater levels have been declining since 1969. The dry winter of 1976-77 accelerated the decline. Without some recharge events, groundwater supplies will start limiting upland water supplies.

Upper portions of Reynolds Creek dried up during the summer of 1977. The effects on the native trout populations are yet to be determined.

Progress Reports (Achievements)

Publications and reports, whether completed or underway, are listed. For those that are underway, the investigations were generally done or completed in this reporting year. References are grouped according to the work plan sections.

Appendix Material

More detailed material is included in the Appendix to support portions of the progress reports.

A summary of principal accomplishments is included for highlighting the progress reports.

A copy of the approved Work Plan for FY 1978 is also included.

STAFF

Name	Title	Service Dates*
Aaron, Virginia M.	Hydrologic Technician (perm., 35 hr/wk)	
Brakensiek, Donald L.	Research Hydraulic Engineer (LL and RL)	
Burgess, Michael D.	Electronic Technician (perm., 39 hr/wk)	
Butler, Donna M.	Administrative Officer	
Coon, Delbert L.	Hydrologic Technician	
Cox, Lloyd M.	Hydrologist	
Engleman, Roger L.	Mathematician	
Gidley, Jess R.	Boise St. Univ. Cooperator - Hydrologic Aid	
Hall, Linda	Boise St. Univ. Cooperator - Technician	5/16/77-Present
Hanson, Clayton L.	Agricultural Engineer	
Harris, James	Univ. of Idaho Cooperator - Research Technician	7/17/77-Present
Hoagland, Roy M.	Automotive Mechanic	
Hussel, Karen	Range Technician	4/10/77-9/10/77
Johnson, Clifton W.	Research Hydraulic Engineer	
Moreland, Bonnie	Clerk Typist (perm., 35 hr/wk)	
Morris, Ronald P.	Hydrologic Technician	
Perkins, Lee	Hydrologic Technician	
Peterson, E. F.	Clerk Stenographer (perm., 35 hr/wk)	6/5/77-Present
Robertson, David C.	Hydrologic Technician	
Schumaker, Gilbert A.	Soil Scientist	
Smith, Jeffrey P.	Hydrologic Technician	
Stephenson, Gordon R.	Geologist	
Stillings, Sue	Boise St. Univ. Cooperator - Technician	9/17/77-Present
Thomson, Michael S.	Univ. of Idaho Cooperator - Technical Aid	3/1/77-Present
Trautman, Kenneth W.	Engineering Equipment Operator	
Wilson, Glenna A.	Procurement Clerk	
Zuzel, John F.	Hydrologist	

*If other than whole year.

ANNUAL WORK PLAN FOR FY 77

Location and Title of Study. The study will be conducted within the Reynolds Creek Experimental Watershed and adjacent satellite areas within the State of Idaho; the title of the study is "Reynolds Creek Experimental Watershed Study."

Work Plan for FY 1977. The ARS, during the FY 1977 study period, will continue to collect and analyze data for evaluating the effects of grazing management systems on rangeland multiple-use resources. Impacts of grazing systems will be determined by the following studies:

1. VEGETATION

   a. On the Reynolds Creek Experimental Watershed at nine sites, herbage yield and maximum cover will be correlated with yield data. Cover data will be utilized for modifying soil erosion estimates. Soil water data will be collected and processed biweekly at five study sites. Soil water models will be tested with this data. Survival of nursery species will be determined at three sites and an interim report will be prepared for persistence and development of various species.

   b. On the Boise Front area, species change and cover and seedling establishment of indigenous species will be measured on five pastures in the rest-rotation system. Where possible, the rotation will be compared with continuous use and nonuse areas. At least 14 study plots are anticipated.

2. RUNOFF

   a. On the Reynolds Creek Experimental Watershed, runoff rates and amounts will be collected and analyzed for two micro-watersheds, three source watersheds, six tributary watersheds, and two main stem watersheds. Watershed models are being developed and tested for predicting water yield and runoff rates.

   b. On the Boise Front area, streamflow gaging sites will be established at four sites. High and low elevation rest-rotation pastures will be represented in the contributing watersheds. Supporting hydrologic data will be collected

from four dual-gage sites, and two weather stations. Soil water and frost data will be collected at rain gage sites. Watershed models will be developed and tested. Applicability of Reynolds Creek data to the Boise Front will also be evaluated.

3. EROSION AND SEDIMENT

   a. On the Reynolds Creek Experimental Watershed, sediment yield will be evaluated, sediment data collected and analyzed from two microwatersheds, one source watershed, three tributary sites, and Reynolds Creek. Bedload transport will be measured at four sites with Helley-Smith samplers. Soil surface factors will be determined at four dense vegetation sites and five sparse vegetation sites. Erosion and sediment yield data will be utilized to adapt and test prediction equations, such as the modified Universal Soil Loss Equation. The influence of range management on sediment and dissolved solids will be studied.

   b. On the Boise Front area, suspended and bedload material will be sampled on an event basis at four watershed sites. Sediment yield estimates will be established for Boise Front waterhseds.

4. WATER QUALITY

   a. On the Reynolds Creek Experimental Watershed, bacteria determinations, DO, BOD, COD, and conductivity will be sampled at eight sites and complete chemical determinations at two sites. Cyclic bacterial concentrations will be related to snowmelt and storm runoff, suspended sediment, weather variables, such as temperature and solar radiation, and channel characteristics, such as turbulence, to establish nonpoint pollution sources. Acceptable rangeland management practices will be formulated and evaluated that are consistent with downstream water quality goals.

   b. On the Boise Front area, establish water quality sampling activities at four sites. Initial efforts will develop base line water quality data for representing the rest-rotation area and other use areas.

   c. A cooperative research project with the University of Idaho Agricultural Engineering Department is being negotiated on evaluating water quality aspects of rangeland cattle wintering operations. Alternative practices for managing runoff water will be studied.

PROGRESS REPORTS (NARRATIVE)

1. VEGETATION

Personnel Involved

G. A. Schumaker, Soil Scientist	Plan, design, supervise field studies, and coordinate research activities and prepare reports.
C. L. Hanson, Agricultural Engineer	Perform computer analysis relative to field studies and assist in planning field studies.
D. L. Coon, Hydrologic Technician	Assists in data collection and noting field observations including soil moisture measurement and calibration.
Karen Hussel, Range Technician (temporary)	Assists in vegetation data collection and reduction.

a. Reynolds Creek Results

HERBAGE YIELD

Comparisons of grazed and exclosure (ungrazed) treatments have been under investigation since 1971. Site locations are on Figure 1.a.1. Other descriptive information is given in Table 1.a.1. Total yields and nonsage yields and averages for the sites in 1977 are shown in Table 1.a.2. Average yields for 1974-1976 are shown for evaluating the drought effects on yields. Total yields in 1977 on the grazed treatment were considerably higher than ungrazed at four of the study sites, and the average yield from the grazed sites was higher than from the ungrazed.

This difference can be attributed to a greater amount of sagebrush measured on the grazed treatment. A comparison of nonsage yields shows very little difference between the treatments, except at Upper Sheep (sparse) and Reynolds Mountain (dense), where the ungrazed treatment yielded considerably more forage. Average yields for the eight sites show a slightly higher yield on the ungrazed plots.

Higher total yields from some of the grazed sites have been observed other years, but were not attributed to differences in brush harvested from the two treatments as was evident in 1977. It may be premature to speculate as to why these differences occur; however, one possibility is that where grazing occurs, browse of the sagebrush has resulted in greater branching; therefore, a greater amount of annual growth.

The effects of the drought which occurred from late October 1976 through April 1977 were very much in evidence in yields at sites lower than 6,000 feet in elevation. At these sites, rains in May and June were too late to affect yields and, thus, grass and forb yields were less than half those recorded other years. The annual forbs and the cheatgrass apparently germinated and then died before the May and June rains. Yields at higher elevations were average or above due to the same May and June rains.

At the Nettleton grazing site we are studying intensive grazing on an area that has had relatively good management in the past. Yield and cover on the grazed site are compared with the adjacent exclosure, which receives no utilization.

Cattle were turned into the grazed portions of the Nettleton study on June 6 and were removed nine days later. Total yields from the grazed and ungrazed treatments were 473 and 551 pounds per acre, respectively; while nonsage yields were 414 and 507 pounds per acre, respectively. Grass production in 1977 at this site appeared

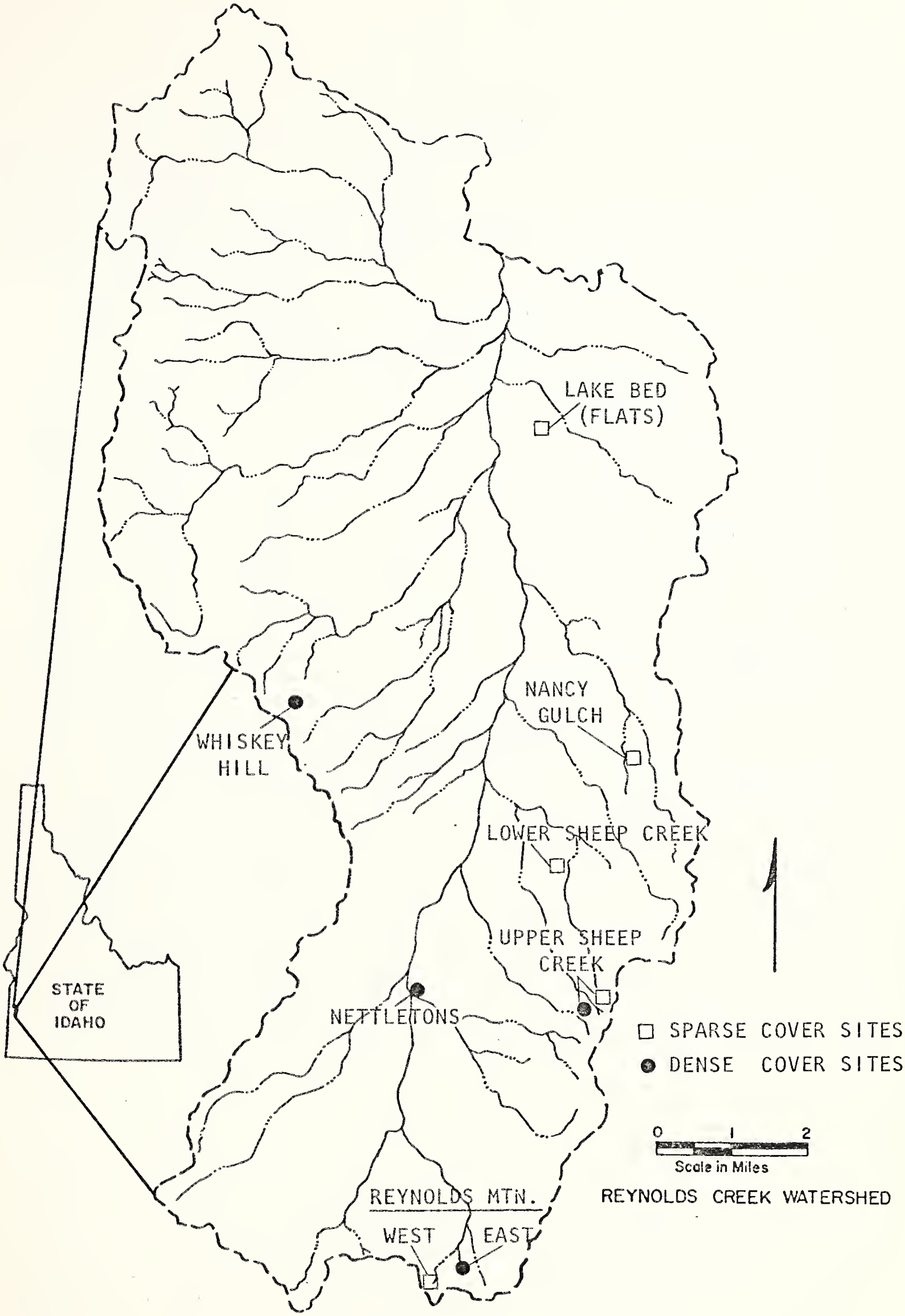


Figure 1.a.1.--Location of study sites.

Table 1.a.1.--Site information.

Site	Ele.	Slope	Aspect of Slope	Precip.	Vege-tative Cover	SCS Hydro. Class.
	feet	*%*		*ins.*	*%*	
			Sparse Vegetation Sites			
Flats	4000	5	N	10	25	B
Nancy Gulch	4600	8	NE	12	25	C
Lower Sheep Creek	5400	16	NW	14	25	B
Upper Sheep Creek	6100	33	SW	20[1/]	25	D
Reynolds Mountain West	6850	5	SW	43[1/]	25	B
			Dense Vegetation Sites			
Reynolds Mountain East	6800	6	NW	43[2/]	50	B
Upper Sheep Creek	6100	33	NE	20[2/]	50	C
Whiskey Hill	5500	15	E	23	50	B

[1/] Snow removed by wind.

[2/] Snow deposition zone.

Table 1.a.2.--Total yields and nonsage yields from eight study sites at Reynolds Creek, 1977.

Site	Total Yield				Nonsage Yield			
	Ungrazed		Grazed		Ungrazed		Grazed	
	1977	1974-1976	1977	1974-1976	1977	1974-1976	1977	1974-1976
	lbs/acre							
Flats	160	463	188	499	74	360	89	413
Nancy Gulch	162	665	380	596	74	400	82	450
Whiskey Hill	878	927	1352	997	488	726	507	598
Lower Sheep	161	528	318	574	86	301	77	336
Upper Sheep (sparse)	547	351	451	480	301	211	113	340
Upper Sheep (dense)	1373	1061	1226	1223	1182	492	1162	747
Reynolds Mountain (sparse)	518	584	571	604	378	362	439	388
Reynolds Mountain (dense)	797	1070	1160	1256	701	441	472	678
1977 AVERAGE	575**1/		706**		411 2/		368	
1974-1976 AVERAGE		706		779		411		494

1/ Means for Total Yield are significantly different at .01 level.

2/ Means for nonsage yields are not significantly different.

to be about average. Winter precipitation was extremely low at the site; however, May precipitation brought the grasses into head early in June. The effects of intensive grazing resulted in decreased productivity in 1977. It appears that production on the ungrazed treatment has also decreased from the earlier years of the study. Nonuse of the area has resulted in a large amount of litter.

In order to subject the area to intensive grazing, cattle were kept in the pasture until the major grass species had shown 80 to 100 percent utilization. If it is assumed that all the nonsage plant material was available for animal consumption, then, based on clippings, the 6.33 acres under grazing provided 2,620 pounds of forage. The usual requirement for an animal is 750 pounds for a 30-day period, or 225 pounds of forage per animal over the 9 days of the grazing period. Then the 11 animal units using the area would have required 2,475 pounds of forage. Thus, the indication is that the animal requirements were met during the grazing period.

COVER DATA FOR EROSION ESTIMATES

Cover measurements and soil surface factor observations are given in Table 1.a.3. Average bare ground measurements for the eight sites are higher for the grazed treatment than for the ungrazed. The Flats, Nancy Gulch, Lower Sheep Creek, and Upper Sheep Creek (sparse) sites all showed high bare ground readings for the grazed treatment; vegetative cover was, in turn, less for the grazed treatment at these sites.

The soil surface factor readings showed a stable erosion class except for slight erosion at Whiskey Hill and the Reynolds Mountain sparse vegetation sites. At the Upper Sheep Creek sparse site, the grazed treatment was slight compared to stable on the exclosure site.

Erosion estimates were made for grazed and ungrazed sites utilizing the cover data. These are discussed in the erosion section.

SOIL WATER DATA

Soil water accretion and depletion data taken during the growing season are shown in Figure 1.a.2. They are average readings from two tubes on each of the treatments, grazed and ungrazed. At the Flats site, the ungrazed treatment shows the accretion because of the rains that occurred in May and June. Accretion is not as apparent on the grazed treatment. It is not certain whether this is a soil difference or due to a difference in treatment. At the Nancy site, accretion was evident during the May and June precipitation, but not on the ungrazed plots. Like the Flats, the soil at Nancy Gulch has a restircting layer which may be affecting water

Table 1.a.3.--Cover measurements and soil surface factor ratings from eight study sites at Reynolds Creek Watershed in 1977.

Site	Treatment	% Vegetation	% Litter	% Rock	% Bare Ground	Soil Surface Factor
Flats	Untreated	14.6	39.4	2.9	43.1	Stable
	Grazed	9.0	22.7	8.2	60.0	Stable
Nancy Gulch	Untreated	21.2	31.6	20.1	27.1	Stable
	Grazed	17.8	34.4	13.4	34.4	Stable
Whiskey Hill	Untreated	75.0	12.8	0	12.2	Slight
	Grazed	70.0	14.2	0	15.8	Slight
Lower Sheep Creek	Untreated	62.6	6.7	9.6	21.1	Stable
	Grazed	49.3	7.9	12.1	30.7	Stable
Upper Sheep Creek (sparse)	Untreated	50.0	5.7	15.0	29.3	Stable
	Grazed	42.6	4.1	12.7	40.6	Slight
Upper Sheep Creek (dense)	Untreated	75.7	22.1	0.4	1.7	Stable
	Grazed	55.4	38.1	0.1	6.3	Stable
Reynolds Mountain (sparse)	Untreated	47.4	16.6	6.6	29.4	Slight
	Grazed	48.1	13.1	5.3	33.4	Slight
Reynolds Mountain (dense)	Untreated	69.4	27.6	0.4	2.6	Stable
	Grazed	73.0	25.6	0.8	0.6	Stable
1977 AVERAGE	Untreated	52.0	20.3	6.9	20.8	
	Grazed	45.7	20.0	6.6	27.7	

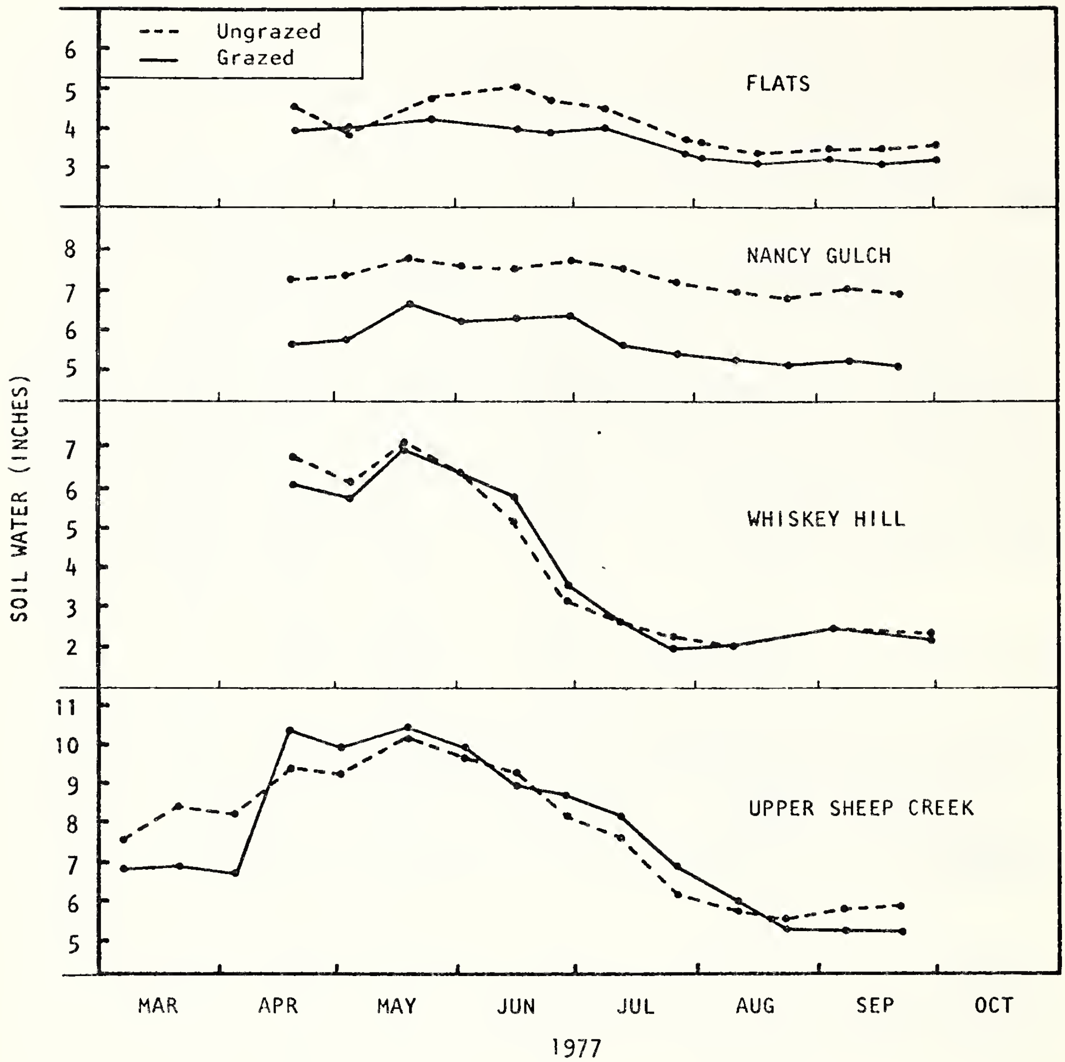


Figure 1.a.2.--Soil water content for grazed and ungrazed treatments at four sites on Reynolds Creek Experimental Watershed, 1977.

intake. At both Whiskey Hill and the Upper Sheep Creek dense vegetation sites, depletion of the soil water was very similar for the grazed and ungrazed treatments.

Soil water depletion curves are being developed from past and current data for 4 key soil water measurement sites on Reynolds Creek Watershed. Soil water models can be calibrated with these depletion curves.

PLANT MATERIALS NURSERIES

Grass, forb and shrub plantings were evaluated for survival and productivity in the Owyhee Mountains of southwest Idaho. Two sites were arid, the third was cool and moist. Of the grasses tested, Nordan crested wheatgrass and pubescent wheatgrass showed promise for arid soils receiving 10 inches of precipitation. Flax and small burnett were the most promising forbs at this site. Shrubs were difficult to establish from seed at the low precipitation site. Numerous wheatgrass selections, mountain rye, smooth brome, and a dryland form of orchardgrass all showed promise at the 12-inch precipitation site. At the cool moist site which receives more than 40 inches of precipitation, survival was high. Smooth brome, meadow foxtail, timothy, and Nordan crested wheatgrass ranked high in performance. Small burnett did well at this site. A decrease in the alfalfa stands was evident at the cool moist site. A protective snow cover was lacking during much of the 1976-77 winter and the plants winter killed.

A draft of a report on the nursery studies is now being reviewed. Publication is planned and reprints will be available.

SAGEBRUSH KILL

Widespread kill of big sagebrush (*Artemesia tridentata*) was very evident at the higher elevations on the watershed following the drought of 1976-77. A survey was completed during the summer which showed that the major sagebrush kills occurred where normally deep snow cover was shallow or absent. Information on factors which affect stands of big sagebrush are important for watershed management. A review of available literature indicates that the 1976-77 kill is unprecedented. A paper is in preparation showing the severity of the kill along with climatic information recorded during the drought period.

b. Boise Front Results

ROTATION GRAZING PROGRAM

The 1977 grazing program was conducted under the guidelines of the established rotation grazing system. Pastures are shown in Introduction Figure 1 and the grazing schedule is given in Table 1.b.1. Grazing began on Low Pasture 4 during mid-April with 206 head of cattle. The drought brought on a decrease in spring water supply in the low pasture and cattle were moved to High Pasture 4 and the Dead Dog segment from early to mid-June. By August 1, cattle were using High Pasture 3. Some cattle were removed on September 7, then from October 23 to November 26 all cattle were rounded up and put in private holdings.

From the sampling of cattle weighed in before turn out and those weighed after round up, the average gain per head for the 200-day grazing period was .99 pounds per day. Gain during the 1977 season was less than previous years, which indicates the drought may have had a more pronounced effect than was anticipated at the time cattle were turned into the pastures.

SPECIES CHANGE AND SEEDLING ESTABLISHMENT

Changes in species composition that are due to rotation of cattle can be monitored on three of the four pastures of the rotation system. No monitoring sites have been established within either of the No. 4 pastures. Comparison of plant frequency data between years and between treatments affords a means of noting any change. Sampling methods are discussed by Hyder.[1/]

It was determined that an 18-inch square quadrant provided good species frequency data for the Boise Front sampling sites since it was able to account for more than 95 percent of the plants that were observed within larger quadrants.

Species observations were from 100 quadrants on each of the treatments at each study site as are identified in Introduction Figure 1. Frequency of species on each study site is shown in Table 1.b.2. The 1977 frequency data will serve as a base line for noting any changes due to cattle use within the rotation. None of the study sites had use in 1977 and any differences between the rotation grazed and exclosure treatments would be due to site variability.

[1/] Hyder, D. N., et al., Ecological responses of native plants and guidelines for management of shortgrass range. USDA Technical Bulletin No. 1503, May, 1975.

Table 1.b.1.--Grazing schedule and type of management for Boise Front Pastures.

Year	Pasture Name			
	H or L, 1 1/	H or L, 2	H or L, 3	H or L, 4
1978	C Early Rest (until seed ripe)	A Graze Season Long	D Rest Season Long (seedling establishment)	B Rest Season Long (for plant vigor)
1979	D Rest Season Long (seedling establishment)	B Rest Season Long	A Graze Season Long	C Early Rest (until seed ripe)
1980	A Graze Season Long	C Early Rest (until seed ripe)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)
1981 (1977)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)	C Early Rest (until seed ripe)	A Graze Season Long

1/ H, 1 or L, 1 refers to High Pasture 1 or Low Pasture 1, etc.

Table 1.b.2.--Frequency count of species within exclosure and on adjacent rotation grazing plots at four sites on the Boise Front. Maximum frequency equals 100.

	Low Pasture 1		Low Pasture 2 (Maynard Gulch)		Low Pasture 2 (spring)		Low Pasture 3	
Common Name	Exclosure	Rotation Grazing	Exclosure	Rotation Grazing	Exclosure	Rotation Grazing	Exclosure	Rotation Grazing
Sandburg bluegrass	89	92	100	96	--	--	100	80
Cheatgrass	100	98	97	83	100	80	97	74
Bottlebrush squirreltail	72	69	88	79	8	9	88	94
Medusa head	--	--	--	--	100	98	--	1
Storksbill	94	93	58	50	79	36	58	26
Fiddleneck	12	13	11	7	--	--	--	37
Phlox	--	14	9	20	--	--	9	1
Salsify	1	3	--	--	--	--	--	43
Other Grasses[1/]	7	8	1	2	9	8	3	--
Other Forbs[1/]	56	57	26	12	17	8	21	30

[1/] Species are identified in field notes but are grouped here for brevity purposes.

The frequency of occurrence for the major species at three of the sites is very similar between treatments. The low pasture three study site does show some variability between the two treatments.

Survival of marked bottlebrush squirreltail (*Sitanion hystrix*) seedlings was noted at three of the study sites, both on rotation grazed treatments and within the exclosure. Average survival was more than 60 percent which was considered good. Rotation grazing was not a factor in survival during the 1977 season. There was not a sufficient stand of seedlings at the Low Pasture 2 spring site within the exclosure because of a dense mat of medusa head (*Taeniatherum spp. caput*). Seedlings were marked on the rotation grazed treatment and showed a 60 percent survival rate.

Bitterbrush leader length was measured during May to estimate the amount of deer use on the area during the winter. However, the deer concentrations were at high elevations during the entire winter due to very little snow and utilization of bitterbrush on the rotation pastures was very slight.

2. RUNOFF

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plan programs and procedures; design and construct facilities for runoff studies; perform analyses and summarize results.
D. L. Brakensiek, Research Hydraulic Engineer	Streamflow and infiltration modeling.
C. L. Hanson, Agricultural Engineer	Test various components in runoff models most applicable to rangelands.
R. L. Engleman, Mathematician	Perform data compilation and assist in analyses.
J. P. Smith, R. P. Morris, and V. M. Aaron, Hydrologic Technicians	Data collection, compilation, and analyses.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.
Dave Robertson, Hydrologic Technician	Snowmelt runoff.

a. Reynolds Creek Results

(Station locations in Figure 2.a.1.)

MICROWATERSHEDS

Flats: The only runoff from this 2.24 acre microwatershed occurred June 11, 1977. A thunderstorm at 10:30 a.m. brought 0.72 inch of rain with 0.40 inch in the first 2 minutes, an intensity of 12 inches per hour; and an additional 0.22 inch in the next 5 minutes, an intensity of 2.4 inches per hour. The sudden runoff from this intense rain carried much debris into the sediment tank and weir which fouled the recorder float and destroyed the runoff record. Again, at 4:37 p.m., a second thunderstorm, with 1-inch diameter hailstones, brought 0.68 inch precipitation in about 6 minutes, an intensity of 6.6 inches per hour. The recorder float, still fouled from the previous storm, did not operate during this event. However, the Reynolds Creek Outlet runoff station, 3 miles downstream, showed a streamflow increase from 6 to 1119 ft^3/sec during this storm. The increase at Reynolds Outlet was from 4 to 51 ft^3/sec as a result of the 10:30 storm.

The Flats microwatershed was on the fringe of the 4:30 p.m. thunderstorm impact area, which centered about 1½ miles northeast of the study area. Peak storm runoff was about 730 $ft^3/sec/mi^2$ from the storm center and about 250 $ft^3/sec/mi^2$ from the 4½ mi^2 runoff producing area.

Nancy Gulch: Runoff from this 3.1 acre microwatershed occurred on June 11, 14, and 20, 1977, from separate thunderstorms of 0.29 inch, 0.47 inch, and 0.49 inch, respectively. Maximum intensities were about 5 minutes in duration in all three storms and were 3.0, 2.8, and 3.6 inches per hour, respectively. Runoff amounts were 12, 41, and 215 ft^3 from the three storms. The largest storm runoff on June 20 accounted for only 4 percent of the precipitation or 0.019 inch.

Streamflow at the Reynolds Creek Outlet station, 7 miles downstream from the Nancy Gulch microwatershed, showed little increase from storms June 14 and 20 because these storms covered small areas and amounts were much less than on June 11.

SOURCE WATERSHEDS

Lower Sheep: Runoff from this 33 acre watershed in 1977 was limited to seepage into the weir pond, but was not sufficient to cause flow through the weir. This is the first time since 1966, when records began, that no runoff has occurred. Precipitation and runoff records for this station are summarized in Table 2.a.1.

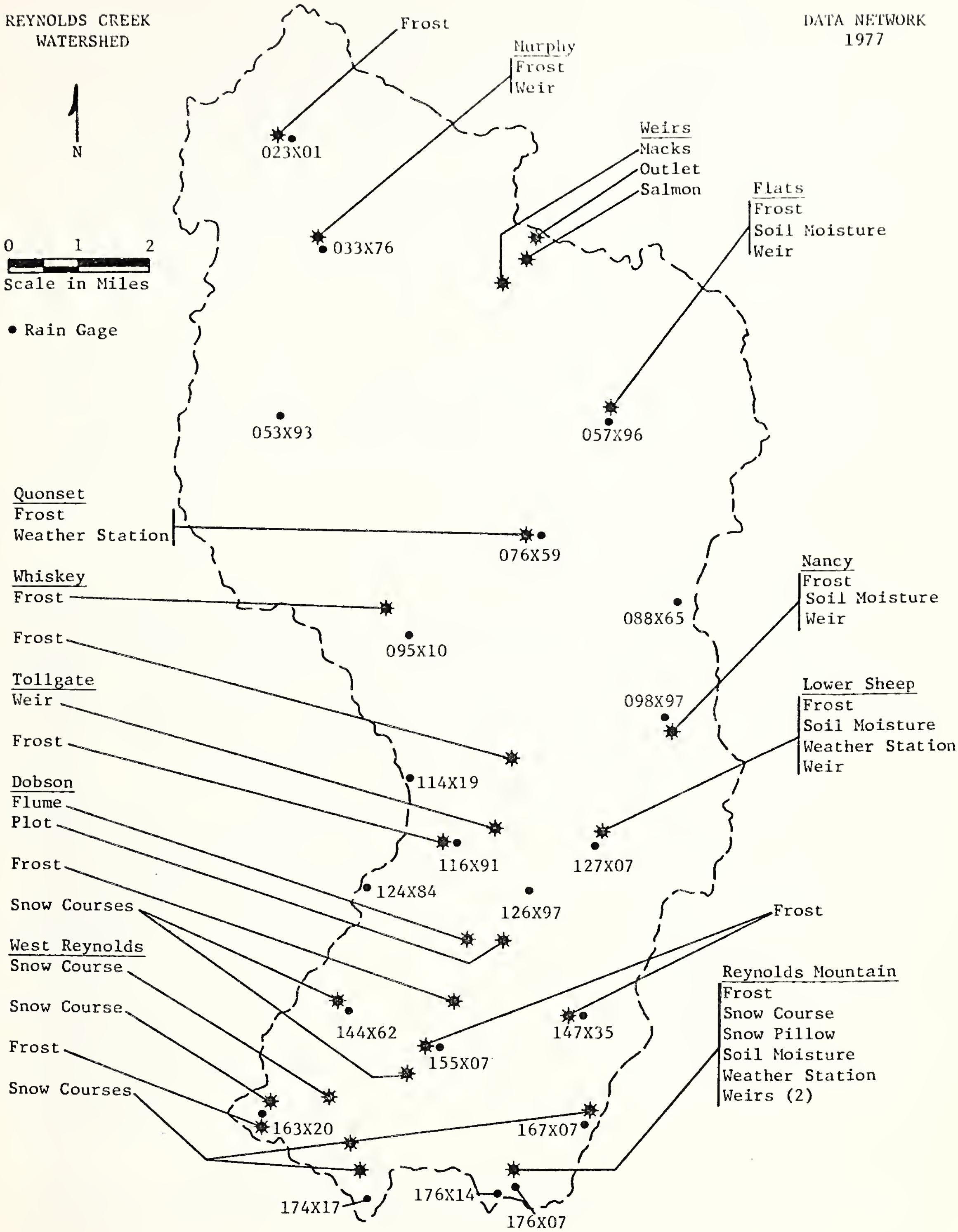


Figure 2.a.1.--Station locations and instrumentation, Reynolds Creek Watershed.

Table 2.a.1.--Water year precipitation, runoff, and peak streamflow, source watersheds, Reynolds Creek Experimental Watershed.

Water Year	Lower Sheep Watershed Precipitation	Lower Sheep Watershed Runoff	Lower Sheep Watershed Peak Streamflow	Lower Sheep Watershed Date of Peak	Reynolds Mountain East Watershed Precipitation	Reynolds Mountain East Watershed Runoff	Reynolds Mountain East Watershed Peak Streamflow	Reynolds Mountain East Watershed Date of Peak	Reynolds Mountain West Watershed Precipitation	Reynolds Mountain West Watershed Runoff	Reynolds Mountain West Watershed Peak Streamflow	Reynolds Mountain West Watershed Date of Peak
	inches	*inches*	*ft³/sec*		*inches*	*inches*	*ft³/sec*		*inches*	*inches*	*ft³/sec*	
1963	16.98	--[1/]	--	--	37.82	11.11	4.16	Apr. 29	--[2/]	--[3/]	--	--
1964	13.55	--	--	--	40.89	21.02	3.60	May 16	--	--	--	--
1965	20.86	--	--	--	66.10	34.87	10.70	Dec. 23	--	25.00	9.29	Dec. 23
1966	6.81	--	--	--	28.36	9.86	1.43	May 5	--	7.39	1.87	Apr. 8
1967	18.73	0.34	1.41	Jan. 21	50.45	21.01	5.44	May 22	--	17.18	5.10	May 22
1968	11.30	0.02	0.08	Feb. 18	31.97	6.72	1.48	Aug. 10	--	6.31	1.97	Feb. 23
1969	14.12	0.52	0.49	Jan. 20	37.45	22.43	3.88	May 12	37.37	17.26	4.20	May 10
1970	14.24	0.02	0.05	Jan. 27	39.60	20.06	5.89	May 17	37.95	20.24	12.33	May 17
1971	17.68	0.31	0.20	Mar. 12	57.96	31.06	5.77	May 4	45.75	21.41	10.24	May 4
1972	13.82	0.91	2.08	Jan. 22	50.51	33.52	6.26	Jun. 6	45.98	29.56	6.31	May 14
1973	12.20	0.01	0.02	Apr. 17	31.01	13.24	3.31	May 8	28.40	10.02	5.35	Apr. 27
1974	10.28	0.26	0.38	Mar. 15	45.54	26.64	4.33	May 7	38.67	19.77	5.61	May 7
1975	14.89	0.73	0.90	Feb. 13	51.57	27.93	9.27	Jun. 2	42.83	21.24	14.28	Jun. 2
1976	14.46	0.55	0.31	Mar. 17	42.51	22.35	4.59	May 13	--	16.38	4.09	May 2
1977	6.87	0	0	--	21.12	3.44	0.93	Apr. 16	--	2.31	0.72	Apr. 16
MEAN	13.79	0.33	0.54		42.19	20.35	4.74		39.56	16.47	6.26	

[1/] Runoff station record began in 1966.

[2/] Precipitation record began in 1968 and terminated in 1975.

[3/] Runoff station record began in 1964.

Reynolds Mountain East: Runoff from this 100 acre watershed was 3.44 inches in 1977, the lowest recorded since records began in 1961. Precipitation at rain gage 176X07 on this watershed was 21.1 inches, about one-half normal, Table 2.a.2. Precipitation, runoff, and peak flow rates, 1963-77, are summarized in Tables 2.a.1, 2.a.2, and 2.a.3 (additional information in Appendix I). Peak water year streamflow was only 0.93 ft^3/sec, the lowest of record. The stream was completely dry in August and September, which was the first time this spring-fed stream had been dry since 1961. Water year runoff was only about half that of 1968, the previous low year of record.

Reynolds Mountain West: Runoff from this 126 acre watershed was 2.31 inches in 1977, the lowest of record. Precipitation, runoff, and peak flow rates are summarized in Table 2.a.1. Peak snowmelt streamflow, 0.72 ft^3/sec, was extremely low and the stream was completely dry during August and September.

TRIBUTARY WATERSHEDS

Salmon Creek: Runoff from this 8990 acre watershed was 0.62 inch in 1977, the lowest of record and about 20 percent of the 13-year mean. Peak streamflow of 103 ft^3/sec occurred June 11, 1977, as a result of a thunderstorm. Streamflow at the weir was reduced to a mear trickle, about 1 gallon per minute, in September. Precipitation, runoff, and peak streamflow rates are summarized in Table 2.a.4.

Murphy Creek: Runoff from this 306 acre watershed, a tributary to Salmon Creek, was 1.42 inches in 1977, the lowest of record and about 19 percent of the 11-year mean. Peak streamflow of 1.2 ft^3/sec occurred June 11, 1977. The stream was dry in July, August, and September. Precipitation, runoff, and peak streamflow rates are summarized in Table 2.a.4.

Macks Creek: Runoff from this 7846 acre watershed was 0.43 inch in 1977, the lowest of record and about 17 percent of the 12-year mean. Peak streamflow of 19 ft^3/sec occurred June 11, 1977, from a thunderstorm. Streamflow at the weir was only about 3 gallons per minute in September. Precipitation, runoff, and peak streamflow rates are summarized in Table 2.a.4.

Dobson Creek: Runoff from this 3482 acre watershed was 2.86 inches in 1977, the lowest in 5 years of record. Peak streamflow of 9 ft^3/sec occurred April 24 from snowmelt. The stream was dry for 2 weeks in August. Precipitation, runoff, and peak streamflow rates are summarized in Table 2.a.4.

Summit and *Whiskey Hill:* Runoff stations terminated prior to 1977.

Table 2.a.2.--Water year precipitation (inches) at three locations on Reynolds Creek Watershed.[1/]

Site	Elevation	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
076X59	3965	1977	.280	.147	.070	.467	.730	.575	.120	1.726	1.657	.470	.510	.570	7.322
		1963-77	.959	1.195	1.242	1.607	.757	.934	.838	.693	1.495	.273	.748	.498	11.239
116X91	4760	1977	.757	.090	.176	.708	1.176	1.394	.405	2.510	1.594	.575	.913	1.161	11.459
		1963-77	1.612	2.109	2.429	2.856	1.421	1.753	1.690	1.119	1.719	.423	.695	.761	18.587
155X07	5410	1977	1.123	.220	.225	1.059	1.726	2.264	.316	3.390	1.414	.774	1.690	1.285	15.486
		1963-77	2.192	3.556	3.856	4.932	2.537	2.886	2.253	1.647	2.050	.648	1.079	.989	28.624
176X07	6760	1977	1.426	.447	.350	1.890	2.699	3.986	.411	4.159	2.165	1.096	1.255	1.233	21.117
		1963-77	2.461	5.584	6.178	8.505	4.215	4.355	3.393	2.285	2.452	.590	1.096	1.076	42.190

[1/] Rain gage locations are shown in Figure 2.a.1. For more information on water year precipitation, see Appendix I.

Table 2.a.3.--Water year runoff, 1977 and mean of record.

Month	Reynolds Creek Outlet		Reynolds Creek Tollgate		Reynolds Mountain East Watershed	
	1977 Runoff	1963-77 Runoff	1977 Runoff	1963-77 Runoff	1977 Runoff	1963-77 Runoff
	inches					
Oct.	0.029	0.027	0.087	0.090	0.158	0.146
Nov.	0.033	0.051	0.089	0.145	0.154	0.248
Dec.	0.033	0.183	0.074	0.222	0.060	0.407
Jan.	0.037	0.431	0.078	0.645	0.077	0.432
Feb.	0.036	0.272	0.082	0.424	0.097	0.438
Mar.	0.035	0.475	0.101	1.007	0.141	0.600
Apr.	0.032	0.575	0.356	1.719	1.414	2.695
May	0.052	0.623	0.439	3.219	1.031	9.781
June	0.047	0.318	0.182	1.506	0.281	4.846
July	0.006	0.049	0.021	0.259	0.031	0.571
Aug.	0.004	0.022	0.001	0.051	0	0.108
Sep.	0.003	0.014	0.002	0.036	0	0.081
Total	0.348	3.040	1.513	9.324	3.444	20.353

Table 2.a.4.--Water year precipitation runoff, and peak streamflow, Tributary Watersheds, Reynolds Creek Experimental Watershed.

Water Year	Salmon Creek Precipi-tation	Salmon Creek Runoff	Salmon Creek Peak Streamflow	Murphy Creek Precipi-tation	Murphy Creek Runoff	Murphy Creek Peak Streamflow	Macks Creek Precipi-tation	Macks Creek Runoff	Macks Creek Peak Streamflow	Dobson Creek Precipi-tation	Dobson Creek Runoff	Dobson Creek Peak Streamflow
	inches	*inches*	*ft³/sec*	*inches*	*inches*	*ft³/sec*	*inches*	*inches*	*ft³/sec*	*inches*	*inches*	*ft³/sec*
1963	22.63	--	--	16.08	--	--	--	--	--	36.12	--	--
1964	19.90	--	--	15.76	--	--	--	--	--	32.48	--	--
1965	33.51	9.65	1523	26.81	--	--	--	--	--	40.89	--	--
1966	10.27	1.05	10	6.96	--	--	--	0.61	12	23.78	--	--
1967	22.77	2.24	85	17.58	5.62	8.0	--	1.54	90	39.56	--	--
1968	14.73	.77	34	16.79	1.72	4.1	--	0.49	44	32.54	--	--
1969	19.36	3.14	209	19.19	8.61	16.3	19.90	2.93	307	40.61	--	--
1970	24.96	3.07	210	29.87	6.58	18.4	19.29	1.92	241	41.67	--	--
1971	24.35	3.61	132	28.65	11.09	9.7	23.65	3.79	281	52.68	--	--
1972	22.74	5.50	201	22.83	14.27	13.1	23.43	4.84	138	42.29	--	--
1973	17.35	2.14	55	17.95	5.04	4.6	15.93	1.76	54	28.93	7.62	49
1974	16.80	3.31	53	17.41	9.57	5.0	15.54	3.72	71	38.94	17.42	82
1975	20.43	3.54	92	21.96	11.01	11.1	22.68	4.79	142	41.85	16.78	65
1976	22.81	2.38	19	22.50	8.10	4.1	21.02	2.67	33	38.37	12.97	43
1977	12.92	0.62	103	13.44	1.42	1.2	14.74	.43	19	20.67	2.86	9
MEAN	20.37	3.16	210	19.59	7.55	8.7	19.58	2.46	119	36.76	11.53	50

Table 2.a.5.--Water year precipitation, runoff, and peak streamflow for mainstem watersheds.

	Reynolds Creek Outlet				Reynolds Creek at Tollgate			
Water Year	Precipitation[1]	Runoff	Peak Streamflow	Date of Peak	Precipitation[2]	Runoff	Peak Streamflow	Date of Peak
	inches	*inches*	ft^3/sec		*inches*	*inches*	ft^3/sec	
1963	25.03	1.85	2331	Jan. 31	31.07	--	--	--
1964	15.25	2.45	188	Jan. 25	24.25	--	--	--
1965	26.83	7.05	3850	Dec. 23	38.93	--	--	--
1966	9.05	0.76	59	Apr. 1	13.79	3.55	59	Apr. 1
1967	19.68	2.19	265	Jun. 7	28.10	9.09	288	Jun. 7
1968	14.20	0.61	327	Feb. 21	21.51	3.08	186	Feb. 21
1969	16.85	3.60	900	Jan. 21	29.11	11.47	405	Jan. 21
1970	20.13	2.70	729	Jan. 27	31.35	9.64	240	Jan. 27
1971	24.96	4.78	540	Jan. 18	41.89	14.98	193	May 6
1972	22.13	6.07	678	Mar. 2	38.12	16.45	271	Mar. 2
1973	16.19	1.85	166	Apr. 17	25.18	6.00	147	Apr. 17
1974	17.14	4.37	291	Mar. 29	29.53	12.75	195	Mar. 29
1975	19.57	4.12	281	Mar. 25	31.18	13.31	231	Jun. 2
1976	20.34	2.84	140	Apr. 5	29.90	10.05	130	May 10
1977	11.46	0.35	1119	Jun. 11	15.54	1.51	17	Apr. 8
MEAN	18.59	3.04	791		28.63	9.32	197	

[1]Rain gage No. 116X91.

[2]Rain gage No. 155X07

MAIN STEM WATERSHEDS

Reynolds Creek Outlet: Runoff from this 57,700 acre, 90.16 mi^2, watershed was only 0.348 inch in 1977, the lowest of record and about 11 percent of the 15-year mean, Table 2.a.3. Peak streamflow of 1119 ft^3/sec occurred June 11, 1977, from a thunderstorm that covered the 4.5 mi^2 northeast section of the Reynolds Creek Watershed, the highest peak streamflow from thunderstorm runoff recorded since records began in 1962. During the irrigation season, nearly all available streamflow above the Reynolds Creek Outlet station was diverted for irrigation, which greatly reduced streamflow at the station. Precipitation, runoff, and peak streamflow rates are summarized in Table 2.a.5 (additional information in Appendix I).

Reynolds Creek Tollgate: Runoff from this 13,453 acre, 21.02 mi^2, watershed was 1.51 inches in 1977, the lowest of record and about 16 percent of the 12-year mean, Table 2.a.3. Peak streamflow was only 17 ft^3/sec, about one-third the previous low in 1966. Precipitation, runoff, and peak streamflow rates are summarized in Table 2.a.5 (additional information in Appendix I).

WATERSHED MODELS

Infiltration: A key component in the development of procedures for predicting water yield and runoff rates is the infiltration process. The infiltration process should be modeled as accurately as possible since it determines how much of the water at the soil surface becomes available for movement into and through the soil profile and how much will become surface runoff. Water in the soil, of course, is stored for plant use or moves through the soil becoming groundwater recharge or return flow to streamflow and/or flow discharging from springs. The infiltration process is important to the land watershed manager because it may be modified by watershed management practices.

Many models or equations have been proposed for the infiltration process. These range from simple or complex algebraic equations to various approximations to the more physical-based equations. A review of the most-used infiltration equations was prepared by Brakensiek (1977). At the Northwest Watershed Research Center, work is presently concentrating on adapting the Green and Ampt equation for watershed application.

In the Green and Ampt equation, the infiltration rate (f) is related to the infiltration amount (F) by the relationship

$$f = K\left(1 + \frac{nS}{F}\right) \quad .$$

Since $F = n(L)$, the equation can be rewritten

$$f = K\left(1 + \frac{S}{L}\right)$$

where K = effective hydraulic conductivity, cm/hr; S = effective capillary pressure at the wetting front, cm; n = fillable porosity; F = infiltration amount, cm; f = infiltration rate, cm/hr; L = wetted depth, cm. The Green and Ampt infiltration equation as a time function is written

$$K(t/n) = L - S\,\ell n\,(S + L/S)$$

or

$$Kt = F - nS\,\ell n\,(1 + F/nS)$$

where t = time in hours, and ℓn is the natural logarithm.

Research on estimation procedures for the Green and Ampt infiltration parameters has utilized infiltrometer data. The S and K parameters are estimated and the effective porosity, n, is calculated from soil bulk density data. In last year's progress report, an estimation procedure for the Green and Ampt equation parameters was developed for ponding-type infiltrometer data. A procedure was also developed for averaging the parameters over the study area to give a single estimate for a particular soil type.

Presently, a procedure is being tested that estimates the Green and Ampt parameters for data from a sprinkling-type infiltrometer. The particular sprinkling infiltrometer was one developed by Hamon and used at several test sites in the Reynolds Creek Watershed during the summer of 1972. The fitting procedure for using sprinkler infiltrometer data must account for the time lapse between the start of water application and the occurrence of surface ponding. This is necessary because, prior to surface ponding, the infiltration rate is equal to the water application rate, and after surface ponding or surface saturation occurs, the infiltration rate is controlled by the soil profile hydraulic properties. One advantage of the Green and Ampt equation is that the time required for surface ponding can be easily estimated, given values of the equation parameters. An important conclusion of this study was that the Green and Ampt equation parameters can be satisfactorily estimated from sprinkling-type infiltrometer data.

Experience to date indicates that the Green and Ampt infiltration equation accurately models observed infiltration data, see Figures 2.a.2 and 2.a.3.

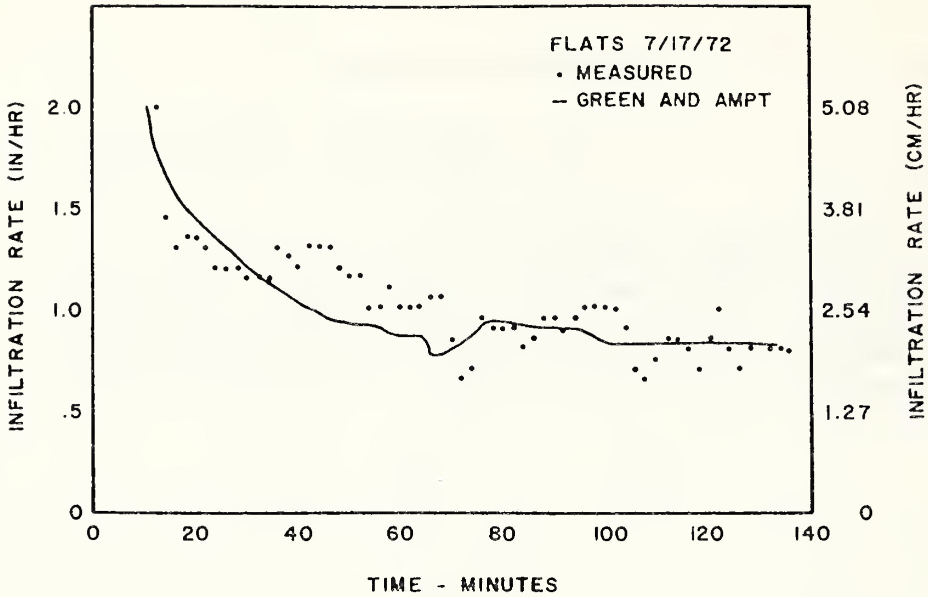


Figure 2.a.2.--Derived and predicted infiltration rate time trend for Flats site, 7/17/72.

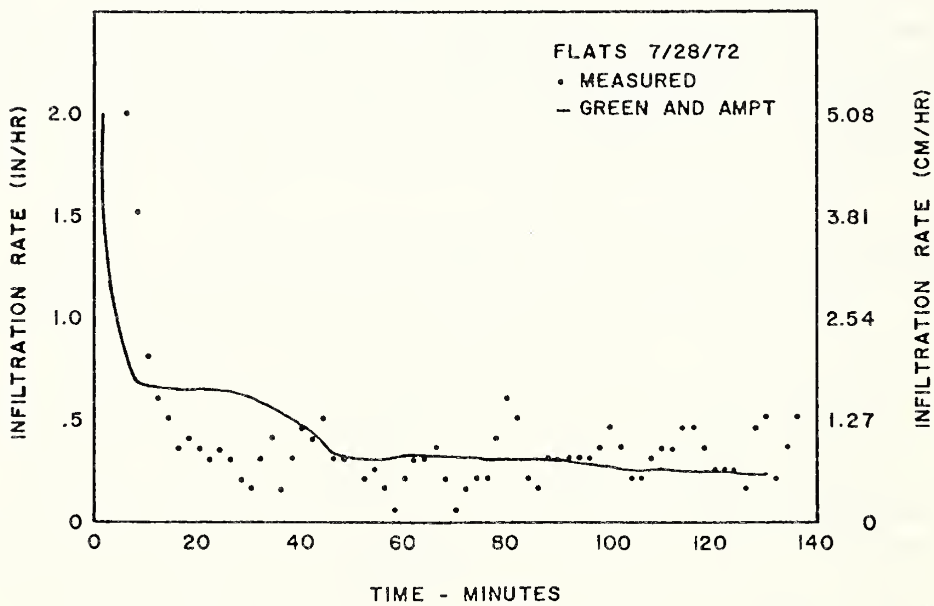


Figure 2.a.3.--Derived and predicted infiltration rate time trend for Flats site, 7/28/72.

To better utilize infiltrometer data, it would be recommended that future tests include the following items:

1. Soil moisture should be measured to a sufficient depth to account for the total zone of water storage.

2. Soil water pressure data should be obtained and utilized for making estimates of the equation parameters. These estimates can be used as a check of the statistically estimated parameters.

3. The time of surface ponding should be observed in addition to the time that surface runoff is observed.

Runoff: A cooperative research project is being established in USDA-SEA-FR for study of the curve numbers used in the Soil Conservation Service runoff equation. This project is in the planning stages at this time. The Northwest Watershed Research Center is participating in this effort to adapt the SCS runoff equation to rangeland watersheds. This will principally involve developing curve numbers for rangeland watersheds.

Runoff Forecasts for Reynolds Creek at Tollgate: The 1977 March through July runoff forecast using maximum snow accumulation at seven snow courses was 1.06 inches compared with 1.10 inches observed. The March 15, 1977, forecast was 1.77 inches compared with 1.10 inches observed (Table 2.a.6).

Table 2.a.6.--Observed and forecast March through July runoff, Reynolds Creek at Tollgate.

Year	Observed Runoff	March 15 Forecast		Maximum Snow Forecast	
		Runoff	Error	Runoff	Error
	inches	*inches*	*percent*	*inches*	*percent*
1973	4.66	2.56	45.0	3.58	23.2
1974	11.00	11.09	0.8	10.41	5.3
1975	12.36	9.58	22.5	12.45	0.7
1976	8.47	8.46	0.1	7.71	9.0
1977	1.10	1.77	60.6	1.06	4.0

Results of a comprehensive study to evaluate March through July runoff forecasts for Reynolds Creek at Tollgate show best results using maximum yearly snow water equivalent at seven snow courses. The March 1 runoff forecasts were best using November to March accumulated precipitation at a rain gage location with maximum snow water equivalent at six snow courses. The March 15 forecasts were best using accumulated precipitation at two rain gage locations with maximum snow water equivalent at six snow courses. (Additional information in Appendix I and II.)

b. Boise Front Results

(Boise Front watershed station locations in Introduction Figure 1.)

STREAMFLOW GAGING STATIONS

Lower Maynard Gulch: This 644 acre watershed is in Low Pasture 2, Introduction Figure 1. The runoff measuring station was completed in September 1977. The stream was completely dry during the late summer and fall, 1977. Figure 2.b.1 is a photograph of the drop-box weir and recorder shelter at this station. Runoff records were not collected during the 1977 water year.

Figure 2.b.1

Upper Maynard Gulch: This 725 acre watershed is in High Pasture 2, Introduction Figure 1. Runoff from this watershed in the 1977 water year was 1.02 inches (Table 2.b.1). The peak streamflow was

Table 2.b.1.--Water year runoff, Boise Front Watershed, 1977.

Month	Upper Maynard Gulch	Highland Creek
	inches	
October	0.120	0.195
November	0.135	0.207
December	0.147	0.215
January	0.147	0.216
February	0.112	0.171
March	0.111	0.192
April	0.088	0.165
May	0.096	0.162
June	0.048	0.071
July	0.003	0.028
August	0.004	0.052
September	0.013	0.079
Year Total	1.024	1.753

1.35 ft^3/sec on June 10, 1977, from about 2 inches of rain. The stream was not dry in 1977 at this station. Figure 2.b.2 is a photograph of the concrete control section, walkway, and recorder shelter at this station.

Figure 2.b.2

Camp Creek: This 717 acre watershed is in Low Pasture 3, Introduction Figure 1. The runoff measuring station was completed in August 1977. The stream was completely dry during the late summer and fall, 1977. Figure 2.b.3 is a photograph of the 24-inch Parshall flume and recorder shelter at this station. Runoff records were not collected during the 1977 water year.

Highland Creek: This 988 acre watershed is in High Pasture 3, Introduction Figure 1. Runoff from this watershed in the 1977 water year was 1.75 inches, Table 2.b.1. The peak water year streamflow was 1.01 ft^3/sec on October 25, 1976, from about 0.5 inch of rain. The peak streamflow June 10, 1977, was 0.86 ft^3/sec. The stream was not dry in 1977. Figure 2.b.4 is a photograph of the concrete control section, walkway, and recorder shelter at this station.

Figure 2.b.3

Figure 2.b.4

Cottonwood Creek: This 10605 acre watershed drains an area west of the other Boise Front watersheds and was previously monitored by the U. S. Geological Survey in 1939 and 1940. Figure 2.b.5 is a photograph of the concrete control section and recorder shelter at this station in Veterans Reserve Park in Boise. The station was completed in September 1977.

Figure 2.b.5

WEATHER STATIONS

The weather station and dual gage precipitation site at the outlet of Maynard Gulch were completed during February, 1977 (Introduction Figure 1). Soil water, soil frost, pan evaporation, air temperature, relative humidity, and wind direction and velocity were collected all of the 1977 water year at the high elevation weather station, and since March at the outlet of Maynard Gulch station. These data are now being processed.

The 1977 water year precipitation at the sites on the Boise Front and Boise airport are listed in Table 2.b.2. These data show that there was below average precipitation during the winter months and much above average precipitation during the months of May through September. The total precipitation at the Boise airport was 2.09 inches below average. Gage sites on the Boise Front (Table 2.b.2) caught from 1.68 to 5.68 inches more precipitation than sites at about the same elevation on the Reynolds Creek Watershed (Table 2.a.2).

Table 2.b.2.--Water year precipitation (inches) at four locations on the Boise Front.

Site	Elevation	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
328X86[1/]	2880	1977	--	--	--	--	--	.886	.179	1.895	2.748	.408	.980	.890	--
322X62	3800	1977	.798	.040	.215	.957	1.368	1.360	.447	2.593	2.844	.450	.710	1.214	12.996
314X50	4650	1977	.777	.147	.247	1.733	1.279	2.089	.528	3.155	3.085	.540	.937	1.555	16.072
311X94	5450	1977	1.002	.247	.408	1.136	2.281	2.640	.612	3.450	2.515	.488	1.060	1.332	17.171
Boise Airport	2838	1977	.52	.14	.09	.65	.57	.86	.19	1.80	1.26	.41	.73	1.20	8.42
"		1941-77	.86	1.31	1.35	1.45	1.13	1.05	1.10	1.19	1.05	.21	.32	.49	11.51

1/ Gage installed February, 1977.

3. EROSION AND SEDIMENT

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plan programs and procedures; design and construct facilities for sediment studies; perform analyses and summarize results.
G. R. Stephenson, Geologist	Determine geologic and geomorphic parameters related to sediment yield.
C. L. Hanson, Agricultural Engineer	Test various components in sediment models most applicable to rangelands.
R. L. Engleman, Mathematician	Perform data compilation and assist in analyses.
J. P. Smith, Hydrologic Technician	Data collection, compilation, and analyses.
J. H. Harris, Biological Technician	Data collection and sediment analyses.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.

a. Reynolds Creek Results

(Reynolds Creek Experimental Watershed station locations in Figure 2.a.1.)

MICROWATERSHEDS

Flats: Suspended sediment samples from the 10:30 a.m. thunderstorm June 11, 1977, showed concentrations ranging from 5400 to 10,300 mg/l; however, no samples were collected during the 4:37 p.m. storm on June 11. A total of 3.84 ft^3 of sediment was collected in the 48 ft^3 sediment tank from both storms. The particle-size distribution curve of a sample of this material is shown in Figure 3.a.1 and the median particle-size is 0.07 mm, which is in the silt and very fine sand class. Unfortunately, hail and debris fouled the recorder float and runoff records were lost; therefore, total sediment yields could not be computed for these storms.

Soil loss from rills was measured on two steep, poorly vegetated hillslopes near the Flats Microwatershed following the June 11, 1977, storms. Soil loss was 8.4 tons/acre on Site No. 1 and 6.9 tons/acre on Site No. 2. Both sites were on 25-30 percent slopes. Soil loss from Site No. 3 at the storm center, 30 percent slope, was 16.2 tons/acre. Particle-size distribution curves of soil from these slopes are shown in Figure 3.a.1. Soil samples for these particle-size analyses were taken from the upper 2.5 inches of soil, about the depth of rills, and Sites 2 and 3 had rock fragments and gravel on the surface. Rills did not form on the Flats Microwatershed since slopes were only 5 percent and vegetative cover was about 60 percent. The median particle-size of material from the sediment tank was generally much less than of the surface soil.

Nancy Gulch: Suspended sediment samples from the thunderstorm at 12:08 p.m. on June 20, 1977, showed concentrations from 5400 to 17,000 mg/l, average 11,360 mg/l. Total sediment yield with 215 ft^3 of runoff from this storm was 4.0 ft^3, 1.9 ft^3 was suspended material which passed through the weir and 2.1 ft^3 remained in the sediment tank. The particle-size distribution curve for sediment from the tank is shown in Figure 3.a.1. The D_{50} particle-size, 50 percent finer, of material from the June 20 storm was only 0.03 mm, much finer than material from the Flats sediment tank. The smaller particle-size was probably because of lower rainfall intensity and runoff. Rills were not visible on steep slopes in the Nancy Gulch area. However, a suspended sediment sample from a gulch downstream was 70,100 mg/l during this storm.

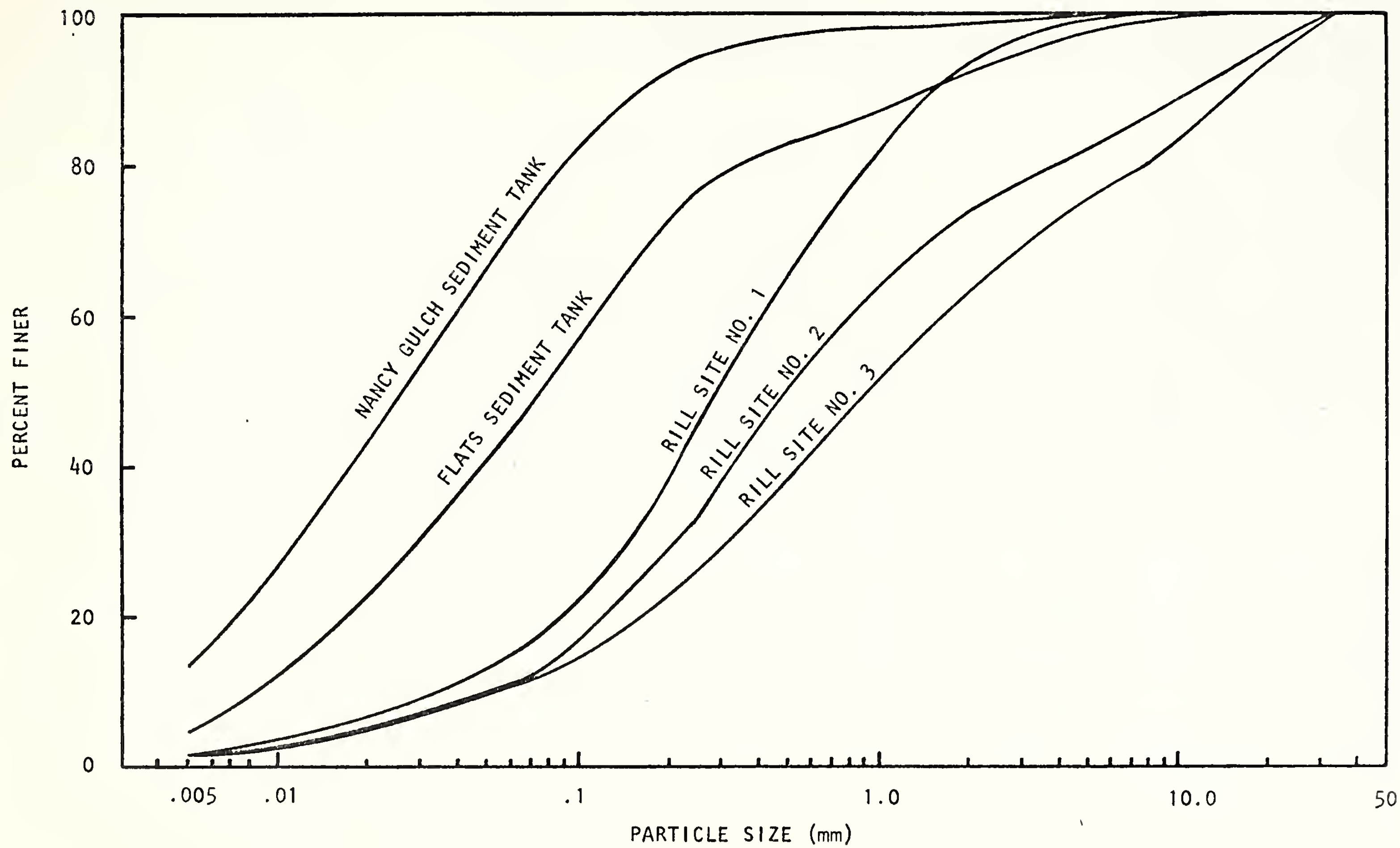


Figure 3.a.1.--Particle-size distribution curves, storm of June 11, 1977.

Reynolds Mountain East: Total sediment yield from this 100 acre watershed was only about 1 ton in 1977, about 7 percent of the 10-year mean (Table 3.a.1). The relationship between yearly runoff and total sediment yield, excluding data from 1970, is shown in Figure 3.a.2. The particle-size distribution curve of sediment from the catchment box is shown in Figure 3.a.3, with similar curves from previous years. The maximum suspended sediment concentration, 170 mg/1, was less than previous years. The trap efficiency of the bedload catchment box was 41 percent of total sediment yield in 1977 (Table 3.a.1).

Table 3.a.1.--Water year sediment yield summary, Reynolds Mountain East Watershed, 1968-77.

Year	Suspended Sediment	Bedload Catchment	Total Sediment	Maximum Concen-tration	D_{50} Particle Size	Sediment Trap Efficiency
	-------------	*tons*	-------------	*mg/l*	*mm*	*percent*
1968	3.75	1.78	5.53	--	0.01	32
1969	11.26	5.72	16.98	1380	0.08	34
1970	22.09	9.05	31.14	650	--	29
1971	10.63	7.49	18.12	650	--	41
1972	11.68	6.65	18.33	827	2.70	36
1973	6.95	2.48	9.43	375	0.03	26
1974	7.75	2.51	10.26	400	0.25	24
1975	8.62	5.61	14.23	260	1.60	39
1976	8.47	3.92	12.39	390	--	32
1977	0.59	0.41	1.00	170	0.50	41

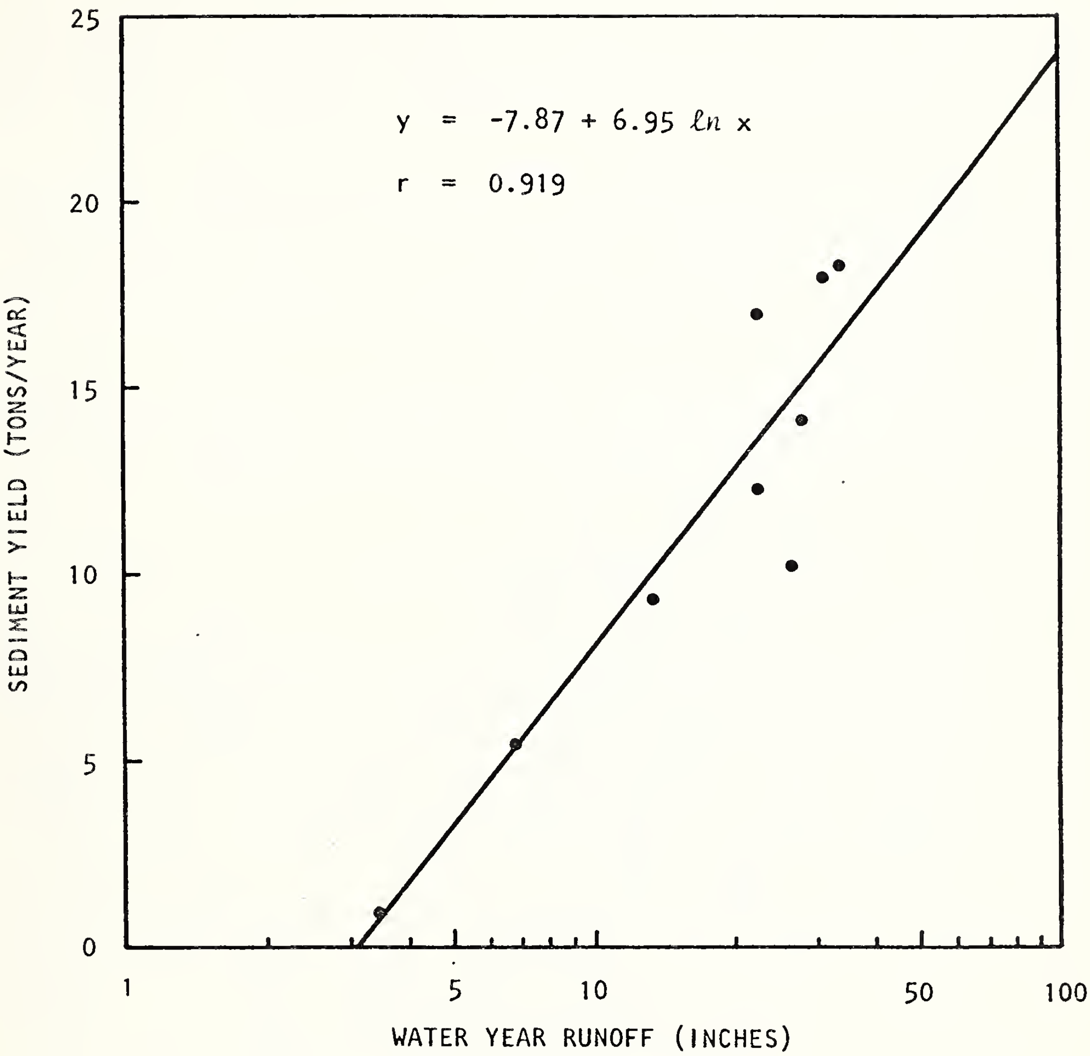


Figure 3.a.2.--Runoff-sediment yield relationship, Reynolds Mountain East Watershed.

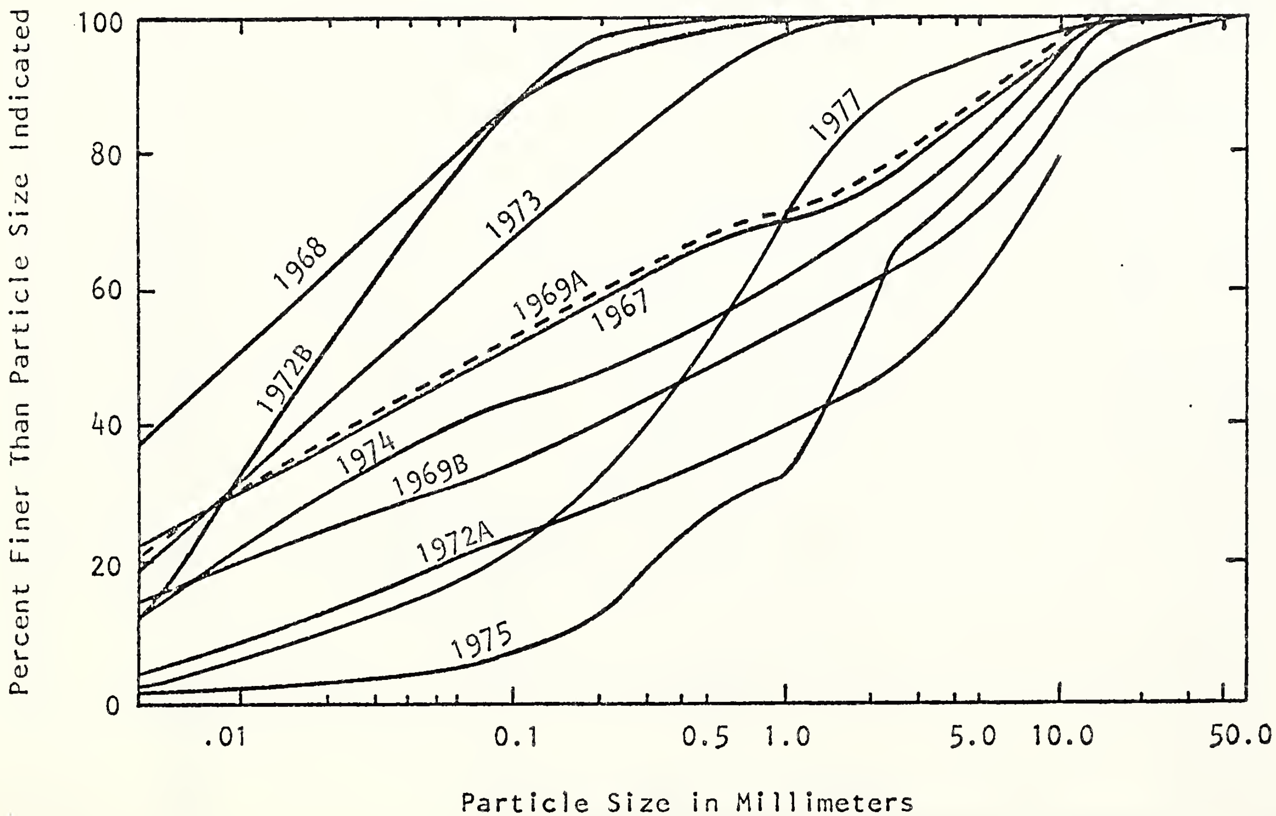


Figure 3.a.3.--Particle-size distribution curves for material from Reynolds Mountain Watershed sediment box.

TRIBUTARY WATERSHEDS

Salmon Creek: Peak streamflow was only 2.7 ft^3/sec, except during the storm of June 11 when the peak was 103 ft^3/sec. Because of the extremely low streamflow, sediment samples were not taken from this stream in 1977. However, sediment yield was obviously very low, similar to the Macks Creek Watershed.

Macks Creek: Peak streamflow was 1.7 ft^3/sec and the maximum sediment concentration was about 50 mg/l in 1977, except on June 11 when the peak streamflow was 19 ft^3/sec. Sediment yield was only about 7 tons in water year 1977 and no measureable bedload material was transported from the watershed.

Dobson Creek: Peak streamflow was 9.1 ft^3/sec, April 24, 1977, and the maximum suspended sediment concentration was 320 mg/l. Sediment yield was only about 25 tons in water year 1977 and bedload sediment transport was too low for measurement.

MAIN STEM WATERSHEDS

Reynolds Creek at Outlet: Peak streamflow was only 6.3 ft^3/sec and maximum suspended sediment concentration was about 30 mg/l in 1977, except on June 11 and 12 when the peak streamflow was 1119 ft^3/sec and the maximum sediment concentration was about 100,000 mg/l. The June 11 storm produced about 3230 tons of suspended sediment from about 4.5 mi^2 and was the largest thunderstorm runoff recorded since records began at this station in 1962. The area of greatest storm impact showed 2-inch deep rills on some hillslopes and stream channels scoured to bedrock in many places. Most of the large boulders and gravel were deposited in the main channel of Reynolds Creek about a mile upstream from the streamflow measuring station. Monthly suspended sediment yields for this station are summarized in Table 3.a.2 and, except for the June 11 thunderstorm, the yield was only about 30 tons. Water year 1977 suspended sediment yield was about 17 percent of the 1967-76 average. No bedload samples were obtained during the year.

Reynolds Creek at Tollgate: Peak streamflow was only 17 ft^3/sec on April 8, 1977, and the maximum suspended sediment concentration was about 340 mg/l. Water year 1977 sediment yield was less than 1 percent of the 1967-76 average yearly amount. Monthly suspended sediment yields are shown in Table 3.a.2. Bedload transport was too low for measurement in 1977.

Table 3.a.2.--Monthly suspended sediment yield from Reynolds Creek Tollgate and Outlet Watersheds, water year 1977.

Month	Reynolds Creek at Tollgate	Reynolds Creek at Outlet
	tons	*tons*
October	0.37	0.96
Nobember	0.48	1.83
December	0.23	2.40
January	0.32	3.13
February	0.75	2.83
March	1.93	2.85
April	22.91	2.37
May	20.26	5.98
June	3.52	3233.28
July	0.29	0.56
August	0.01	0.29
September	0.01	0.18
Water Year Total	51.08	3256.66

BEDLOAD TRANSPORT STUDY

Reynolds Creek Watershed streams were too low in 1977 to transport bedload, except during the June 11 thunderstorm when no samples were obtained. Bedload transport data from the Reynolds Creek Tollgate station in 1975 and 1976 was analyzed to determine the streamflow-bedload transport relationship at the stream center, shown in Figure 3.a.4. The relationship between streamflow and particle-size at the stream center is shown in Figure 3.a.5.

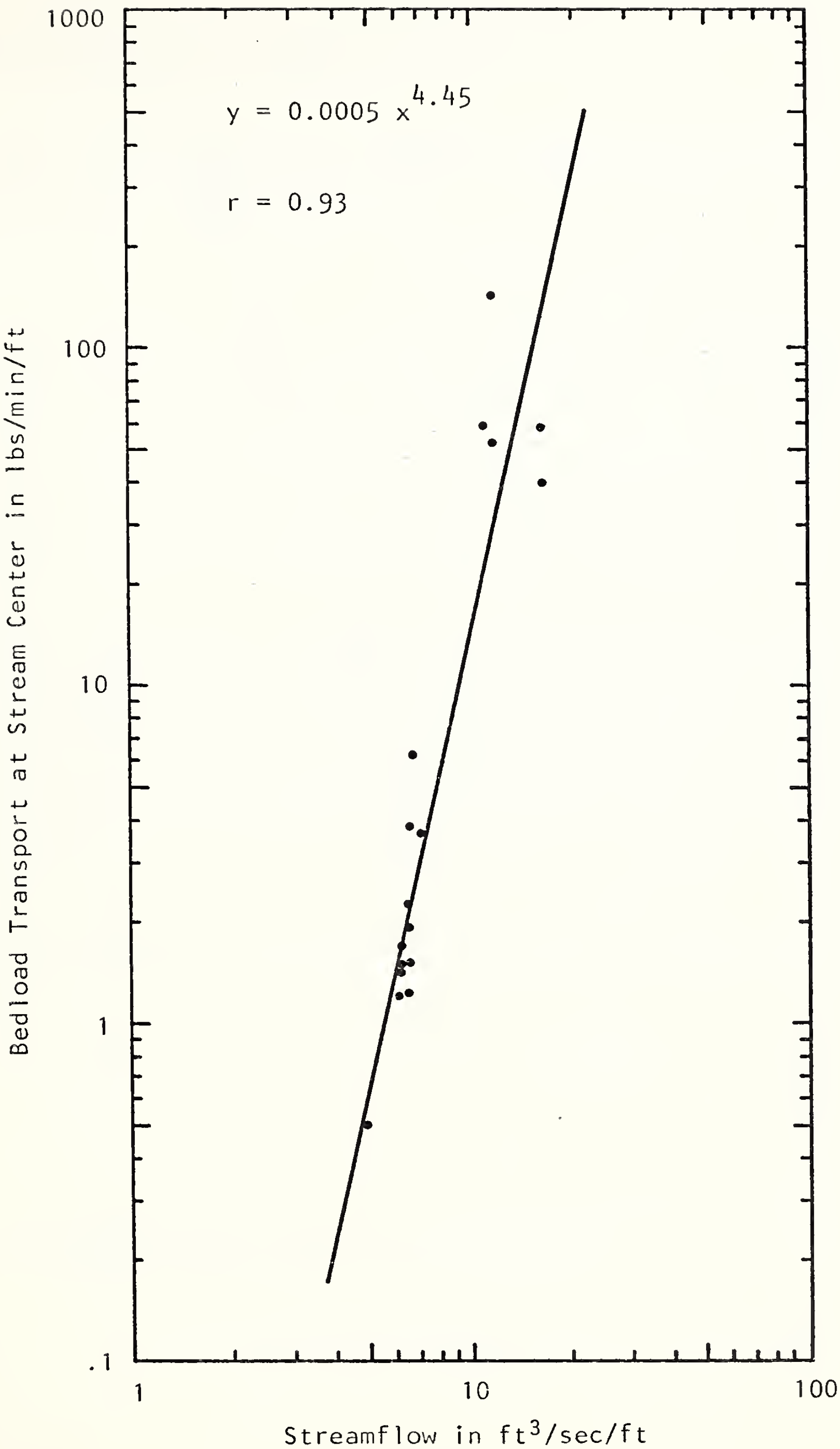


Figure 3.a.4.--Bedload transport-streamflow relationship at stream center, Tollgate Station.

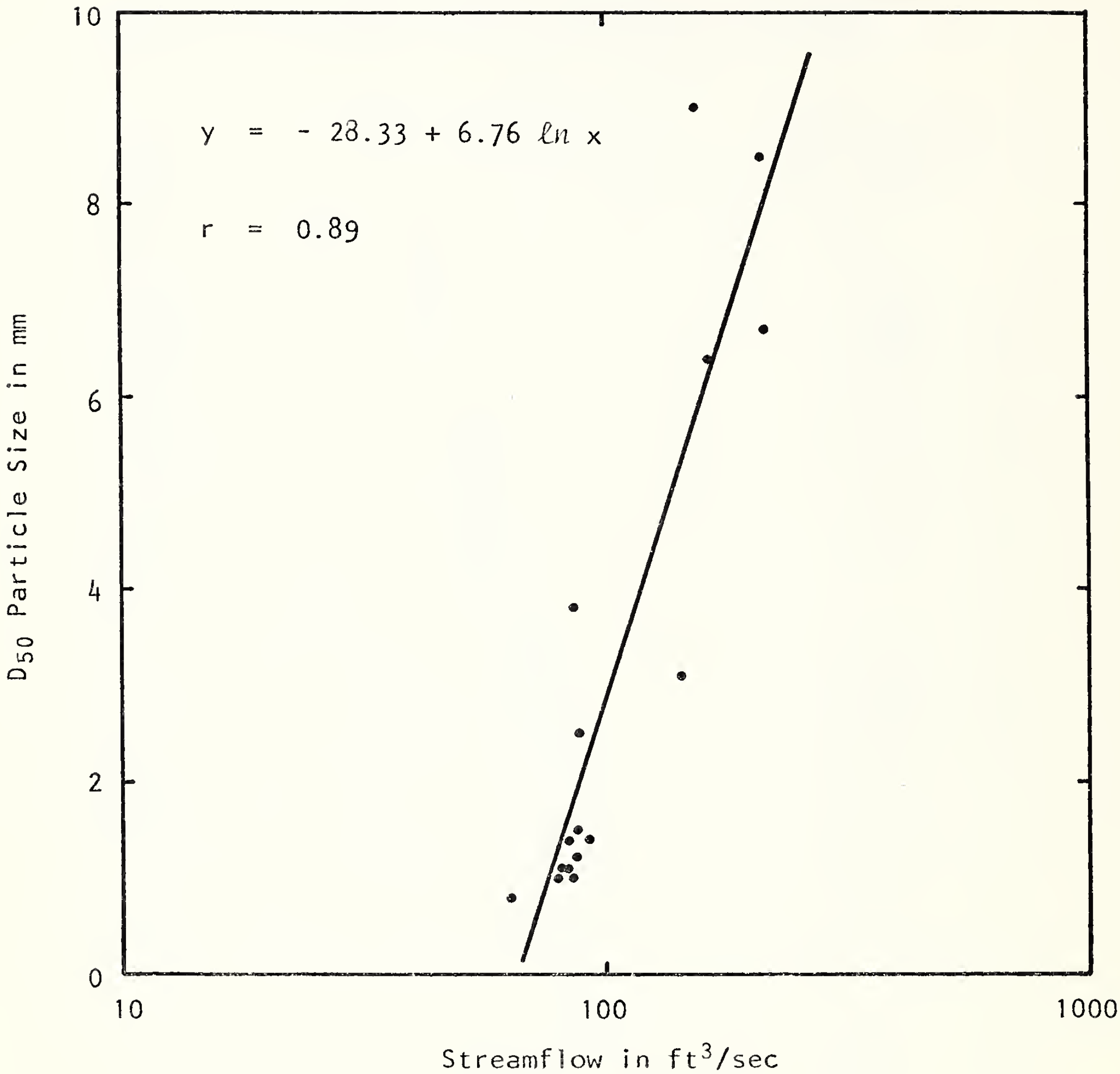


Figure 3.a.5.--The streamflow-D_{50} bedload particle size relationship at stream center, Reynolds Tollgate Station.

SOIL LOSS STUDIES

Soil losses from eight grazed and eight ungrazed vegetation study sites on the Reynolds Creek Watershed were computed by the Universal Soil Loss Equation (USLE)

$$A = R\,K\,L\,S\,C\,P$$

where A is the computed soil loss per unit area; R is the rainfall factor; K is the soil erodability factor; L is the slope length factor; S is the slope gradient factor; C is the cropping or cover factor; and P is the practices factor (P = 1.0 in this study). Values of the USLE factors for the rangeland sites are summarized in Table 3.a.3. The C factors were determined from 1973-77 cover data. Average yearly soil loss from all sites was 0.5 ton per acre from grazed sites and 0.4 ton per acre from ungrazed sites.

Soil losses, computed by the USLE, and measured sediment yields from five Reynolds Creek watersheds are compared in Table 3.a.4. Overall, sediment yields were about 31 percent of computed soil loss, as indicated by the delivery ratios. The computed soil losses in Table 3.a.4 differ from losses at vegetation sites, Table 3.a.3, because watershed USLE factors were determined from a different combination of soil erodability, slope length, slope gradient, and cover values.

Table 3.a.3.--Soil loss computations by the Universal Soil Loss Equation for vegetative study sites, Reynolds Creek Watershed.

Site	Rainfall-Runoff R	Soil Erodability K	Slope Length and Gradient LS	Crop Cover C	Soil Loss A
	Soil Loss Factor				
					tons/acre
Flats					
Ungrazed	17.9	0.28	0.7	0.078	0.27
Grazed	17.9	0.28	0.7	0.078	0.27
Nancy					
Ungrazed	20.9	0.20	1.4	0.029	0.17
Grazed	20.9	0.20	1.4	0.040	0.23
Whiskey Hill					
Ungrazed	29.9	0.15	2.8	0.026	0.33
Grazed	29.9	0.15	2.8	0.024	0.30
Lower Sheep					
Ungrazed	25.4	0.15	4.3	0.013	0.21
Grazed	25.4	0.15	4.3	0.018	0.29
Upper Sheep (Sparse Brush)					
Ungrazed	28.0	0.15	7.6	0.038	1.21
Grazed	28.0	0.15	7.6	0.052	1.66
Upper Sheep (Dense Brush)					
Ungrazed	28.0	0.28	9.3	0.006	0.44
Grazed	28.0	0.28	9.3	0.010	0.73
Reynolds Mountain (Sparse Brush)					
Ungrazed	56.3	0.17	1.7	0.017	0.28
Grazed	56.3	0.17	1.7	0.022	0.36
Reynolds Mountain (Dense Brush)					
Ungrazed	56.3	0.28	1.4	0.013	0.29
Grazed	56.3	0.28	1.4	0.014	0.31

Table 3.a.4.--Measured sediment yield and computed soil loss by the USLE on Reynolds Creek watersheds.

Watershed	USLE Factor R	K	LS	C	P	A	Measured Yield	Delivery Ratio
						tons/ acre	*tons/ acre*	
Summit	18	0.17	4.2	0.05	1.0	0.64	0.34	0.53
Lower Sheep	25	0.17	2.5	0.02	1.0	0.21	0.10	0.48
Upper Sheep	28	0.20	5.6	0.03	1.0	0.94	0.14	0.15
Whiskey Hill	30	0.15	6.1	0.03	1.0	0.82	0.13	0.16
Reynolds Mtn.	56	0.22	3.5	0.02	1.0	0.86	0.19	0.22

b. Boise Front Results

(Boise Front runoff and sediment sampling stations shown in Introduction Figure 1.)

SEDIMENT SAMPLING

Suspended sediment from periodic sampling showed maximum concentrations of 18 and 45 mg/l, minimum concentrations of 1 and 3 mg/l, and average concentrations of 8 and 18 mg/l at Upper Maynard Gulch and Highland Valley Creek stations in 1977, Table 4.b.1. Bedload transport was insignificant.

SOIL LOSS STUDY

Soil losses on six hillslopes, an unimproved road, and a steep eroding streambank on the Boise Front were computed by the USLE using cover, soil, and topographic data collected in 1977. Results of this study are summarized in Table 3.b.1 and show that computed soil loss from the steep streambank was about 50 times greater per unit area than from the hillslope average. Soil loss from the road was nearly 6 times greater per unit area than from hillslopes.

Table 3.b.1.--Computed soil loss from rangeland sites using the Universal Soil Loss Equation, A = RKLSCP.

	Soil Loss Factor					
Site	R	K	LS	C	P	A
Hillslope 1	28	0.32	5.2	0.025	1.0	1.2
Hillslope 2	32	0.24	7.0	0.060	1.0	3.2
Hillslope 3	26	0.32	11.0	0.008	1.0	0.7
Hillslope 4	28	0.37	8.5	0.012	1.0	1.1
Hillslope 5	33	0.32	18.0	0.032	1.0	5.7
Hillslope 6	27	0.32	7.5	0.027	1.0	1.8
Road	30	0.32	3.0	0.450	1.0	13.0
Streambank	50	0.25	19.0	0.450	1.0	106.9

4. WATER QUALITY

Personnel Involved

G. R. Stephenson, Geologist	Responsible for coordinating activities with cooperators. Design collection network and responsible for project completion.
J. F. Zuzel, Hydrologist	Responsible for statistical analysis of data, water quality modeling, and shares the responsibility for aquatic sampling.
J. H. Harris, Biological Technician	Responsible for collection of water samples and laboratory analyses.
M. Scott Thomson, Hydrologic Technician	Shares responsibility for field operations and water sampling.

a. Reynolds Creek Results

Because a 5-year data base of water quality parameters are available from Reynolds Creek, a reduction of sampling sites was initiated. A total of eight sites were monitored this year for biological indicators, including two sites for which complete chemical analyses were determined. Figure 4.a.1 gives the location of the sampling sites on Reynolds Creek and Table 4.a.1 gives a summary of the data from these sites. Because of the severe drought conditions which prevailed, streamflow was very low or ceased entirely at many of the sampling sites. Consequently, the data collected reflect the results of an extremely low flow condition, and also reflect a reduced number of samples during the late spring and summer months. Several of the studies planned for the year could not be carried out because of inadequate streamflow.

DETERMINATION OF NATURALLY OCCURRING BACTERIAL CONCENTRATIONS

Results reported in previous annual reports indicate daily fluctuation in both total and fecal coliform concentrations. The causative factors responsible for these variations are, for the most part, identifiable, but quantitative relationships are not often determined. The work plan for FY 1977 called for quantitative relationships to be made between bacterial concentration and the environmental factors of temperature, sediment concentrations, channel characteristics, solar radiation and streamflow. Because of the drought conditions on Reynolds Creek, the designated sites where these studies were to be performed had inadequate flow to complete the evaluation. Only two sets of samples were taken before the stream at the sites became too low or dried up completely. Analyses of these data may be used for the FY 78 studies as a minimum flow point in the evaluation. Suspended sediment concentrations were negligible and no significant peak flows occurred from storm or snowmelt.

In lieu of the above stream study, a preliminary examination of rangeland soils was done at three moderately heavy grazing sites to determine total and fecal coliform concentrations. Samples were taken randomly from the top 3 cm of the soil. The density of "cow pies" was one per square meter at Site 106, 1.5 per square meter at Site 135, and 3.5 per square meter at Site 166. Site locations are found on Figure 4.a.1. Table 4.a.2 gives the results of these initial analyses. The most probable number method was used for enumeration.

The occurrence of fecal coliforms was surprisingly low or absent even though fecal material was numerous in the area sampled. This preliminary result would indicate that cattle and their resulting fecal material which occur in or immediately adjacent to the streams

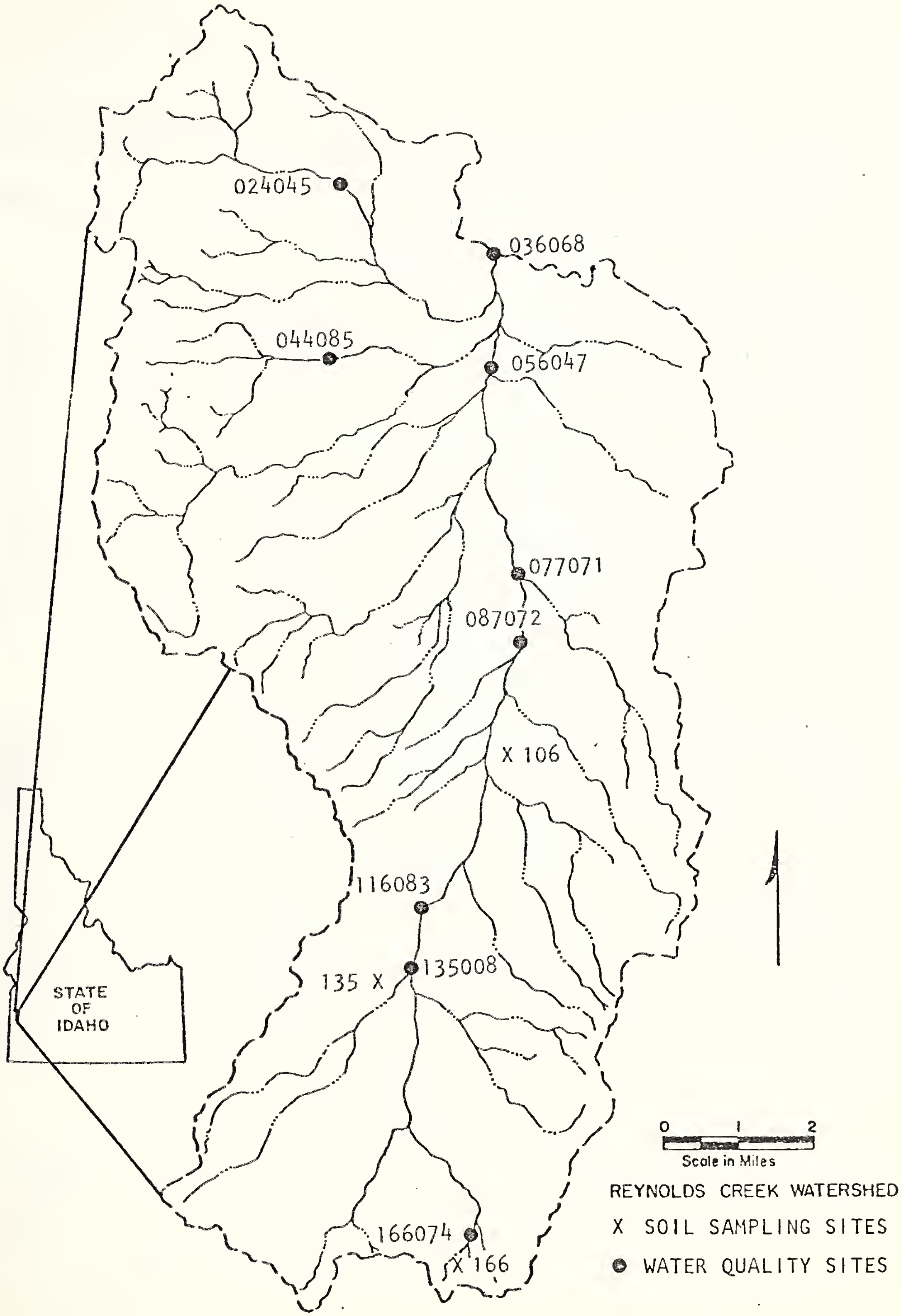


Figure 4.a.1.--Location of water and soil sampling sites for water quality determination.

Table 4.a.1.--Water quality characteristics, Reynolds Creek Watershed sampling sites, 1976-77.

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		REYNOLDS OUTLET (036068)			
pH	units	28	9.80	6.1	8.33
Conductivity	μmhos	34	3708.00	245.00	1278.15
Dissolved solids	mg/l	34	2559.00	169.00	881.94
Calcium	mg/l	8	87.78	44.89	67.03
Magnesium	mg/l	8	40.12	17.63	30.33
Sodium	mg/l	8	184.14	64.37	129.69
Phosphorous	mg/l	8	0.12	0.03	0.06
Nitrate	mg/l	8	0.18	0.01	0.06
SiO_2	mg/l	8	52.20	4.20	33.10
Sodium Adsorption Ratio	ratio	8	4.48	2.04	3.24
Suspended solids	mg/l	30	35.00	0	15.50
Total coliform	cts/100 ml	34	825	0	158
Fecal coliform	cts/100 ml	34	420	0	103
Fecal strep	cts/100 ml	34	1220	0	289
COD	mg/l	32	37.16	4.00	15.78
BOD	mg/l	29	3.00	0	1.23
DO	mg/l	30	12.5	7.00	8.80
		TOLLGATE WEIR (116083)			
pH	units	25	8.60	6.10	7.98
Conductivity	μmhos	29	2331.00	88.00	450.24
Dissolved solids	mg/l	29	1608.00	61.00	307.83
Calcium	mg/l	7	30.06	15.43	20.18
Magnesium	mg/l	7	11.67	6.44	8.61
Sodium	mg/l	7	10.57	7.13	8.38
Phosphorous	mg/l	7	0.08	0.03	0.05
Nitrate	mg/l	7	0.05	0	0.02
SiO_2	mg/l	7	46.20	22.80	31.31
Sodium Adsorption Rate	ratio	7	0.46	0.36	0.39
Suspended solids	mg/l	18	11.00	0	6.20
Total coliform	cts/100 ml	27	1420	0	249
Fecal coliform	cts/100 ml	26	700	0	152
Fecal strep	cts/100 ml	27	1400	0	176
COD	mg/l	5	8.02	0	3.38
BOD	mg/l	2	1.00	0	0.50
DO	mg/l	23	11.00	6.50	9.00
		UPPER SALMON (024045)			
Total coliform	cts/100 ml	19	4080	40	605
Fecal coliform	cts/100 ml	18	4520	40	444
Fecal strep	cts/100 ml	19	2900	1	840
COD	mg/l	2	4.04	0	2.02
BOD	mg/l	0	---	---	---
DO	mg/l	14	9.00	7.50	8.20

(continued)

Table 4.a.1 --continued

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		COTTLE CREEK (044085)			
Total coliform	cts/100 ml	11	2840	35	593
Fecal coliform	cts/100 ml	10	2300	120	546
Fecal strep	cts/100 ml	11	3440	2	1407
COD	mg/l	0	--	--	--
BOD	mg/l	0	--	--	--
DO	mg/l	0	--	--	--
		LOWER REYNOLDS (056047)			
Total coliform	cts/100 ml	36	4000	0	313
Fecal coliform	cts/100 ml	35	1100	0	135
Fecal strep	cts/100 ml	36	11200	0	500
COD	mg/l	33	39.12	2.86	15.21
BOD	mg/l	29	3.00	0	1.30
DO	mg/l	31	14.00	5.50	8.90
		NETTLETON'S BRIDGE (037072)			
Total coliform	cts/100 ml	36	3160	8	557
Fecal coliform	cts/100 ml	35	2728	4	296
Fecal strep	cts/100 ml	36	2280	0	495
COD	mg/l	31	33.12	0	6.73
BOD	mg/l	28	3.00	0	1.10
DO	mg/l	32	11.00	6.00	8.40
		BELOW DOBSON (135008)			
Total Coliform	cts/100 ml	27	1020	0	260
Fecal coliform	cts/100 ml	26	820	0	123
Fecal strep	cts/100 ml	27	4700	0	249
COD	mg/l	25	16.30	0	4.98
BOD	mg/l	23	4.00	0	0.90
DO	mg/l	24	11.50	5.00	8.60
		REYNOLDS MOUNTAIN WEIR (166074)			
Total coliform	cts/100 ml	26	1040	4	166
Fecal coliform	cts/100 ml	25	540	0	82
Fecal strep	cts/100 ml	26	540	0	62
COD	mg/l	0	--	--	--
BOD	mg/l	0	--	--	--
DO	mg/l	21	9.50	3.50	7.38

Table 4.a.2.--Coliform concentrations at three rangeland sites, Reynolds Creek Watershed.

Date	Site	No. of Samples	Average Total Coliform Concentration	Average Fecal Coliform Concentration
			-------- *MPN/gm soil*	---------
3/14/77	106	3	3	0
	135	3	4	1
5/31/77	106	3	32	2
	135	3	3	0
7/29/77	166	20	--*	1

*No analyses for total coliform were done.

are the major sources of fecal coliforms. Buckhouse and Gifford[1/] have also found that the number of fecal colonies drops off rapidly in short distances from "cow pies."

QUALITY OF RUNOFF FROM IRRIGATED PASTURELAND AND RANGELAND

Table 4.a.1 presents the summary of sampled water quality parameters for Reynolds Creek. Previous reports can be used for comparison with the drought conditions of 1976-77. Because of the drought conditions which prevailed during the 1977 water year, considerable changes occurred in the water chemistry of the streams on Reynolds Creek. A comparison of selected chemical parameters for site 116083 located on rangeland, and site 036068, which receives runoff from irrigated land, is given on Figure 4.a.2. The data presented on Figure 4.a.2 are given so that yearly comparisons can be made between these two sites, which receive runoff from different management practices. Data for the same two sites and for the same parameters are given in previous annual reports.

[1/] Buckhouse, J. C. and Gifford, G. F. 1975. Water Quality Implications of Cattle Grazing on a Semiarid Watershed in Southeastern Utah. Journ. Range Mgmt. 29(2): 109-113.

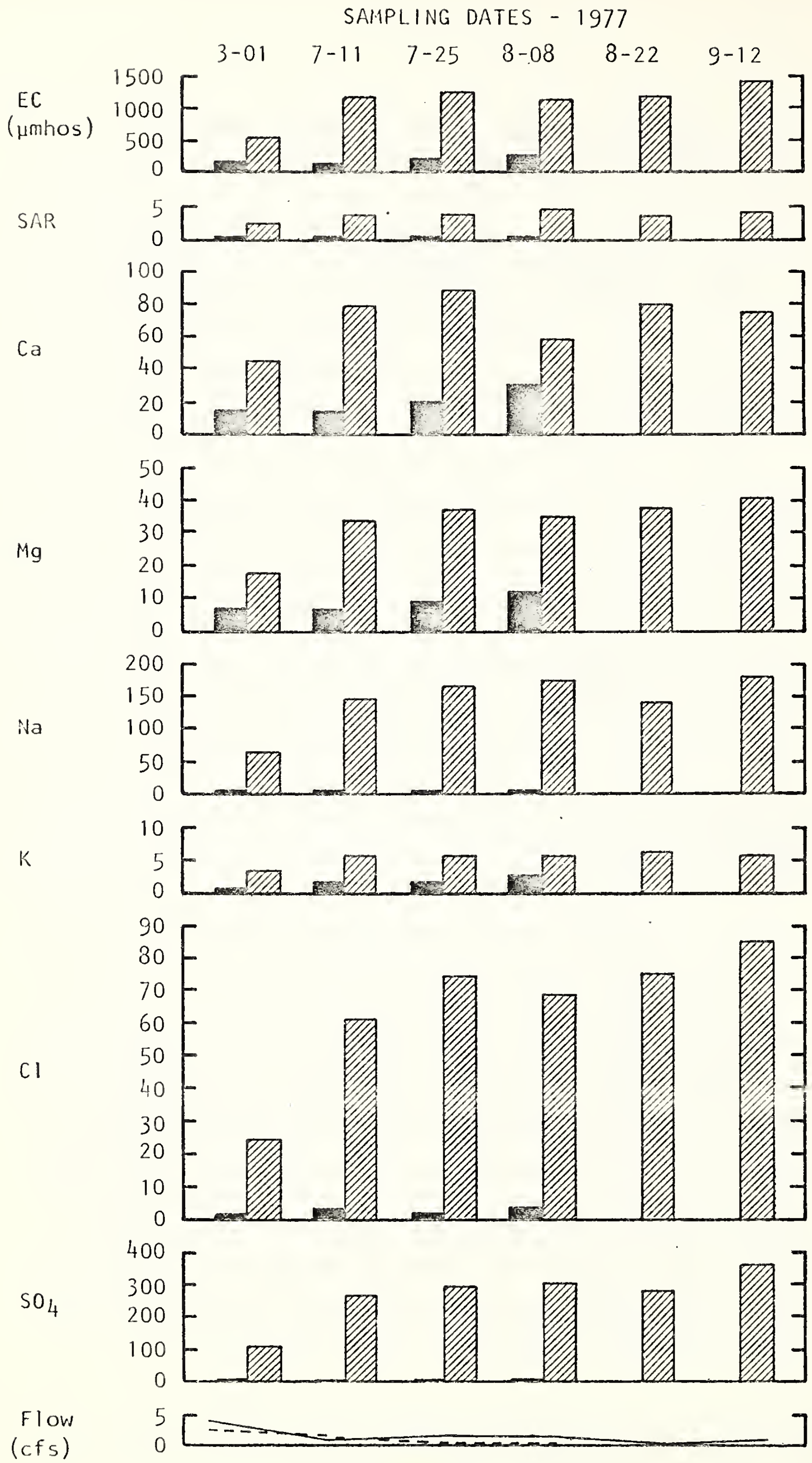
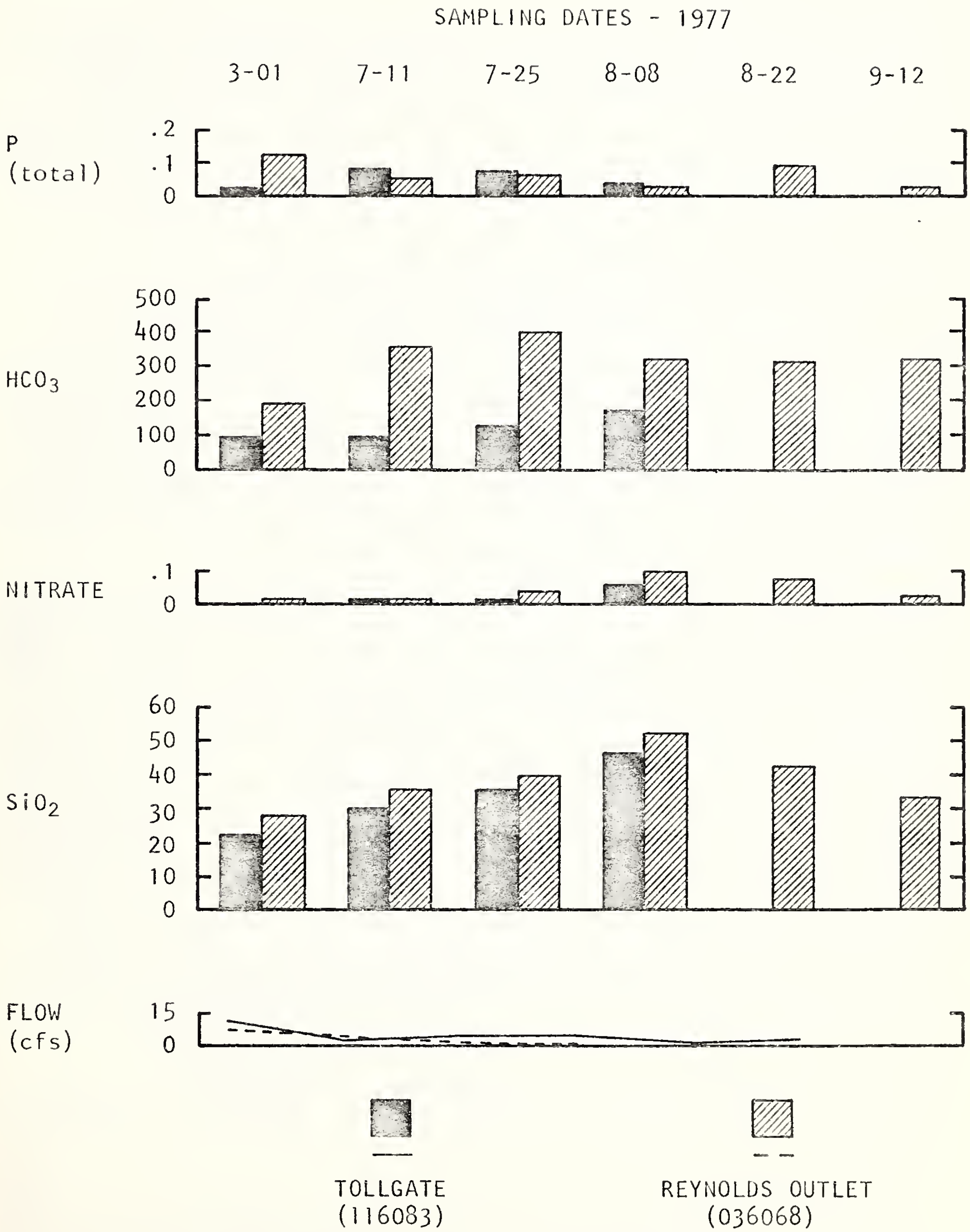


Figure 4.a.2.--Variation in major chemical constituents (mgl) and streamflow between rangeland and irrigated land sites.

Figure 4.a.2.--(continued)



During 1977 the result of the drought did not cause appreciable deterioration in quality of the streams on rangeland. By mid-August, however, many of the stream segments on rangeland were dry or carried such small flows that meaningful samples could not be taken for analyses.

Significant changes in chemical quality of streamflow did occur in late summer at the outlet of the watershed (site 036068) where streamflow is influenced by irrigation runoff. Higher concentrations of sodium were recorded this year than have previously been recorded at this site, causing a low to medium sodium alkali hazard in the waters downstream. A high salinity hazard also occurred in these lower elevation streams from July through September.

INFLUENCE OF RANGE MANAGEMENT PRACTICES ON PRODUCTION OF TOTAL DISSOLVED SOLIDS IN STREAMFLOW

Chemical analyses for TDS have been made to determine the amount of soil material removed in the dissolved state from different parts of the watershed. Since October 1972, 345 chemical analyses have been made to compute TDS. In addition, 130 specific conductance measurements were taken for estimating TDS concentrations between times samples were taken for chemical analyses and at sites where chemical analyses were not determined.

Figure 4.a.3 shows the distribution of TDS volumes produced within the watershed by yearly averages from October 1972 through September 1976. The highest volume during this period, 3046 tonnes per year, was produced from the irrigated portion of the watershed. The northwest part of the watershed, which is under a deferred grazing management practice, is a low volume producer of dissolved solids, whereas the southeast part of the watershed, where open grazing is practiced, produces considerably more. However, it probably isn't correct to relate this difference entirely to different management practices because considerably more runoff occurs in the southern part of the watershed, producing a greater total volume per year of dissolved solids. In fact, when comparing the two areas using amount of total dissolved solids per unit of runoff (TDS in milligrams per liter) the samples from the northwest part of the watershed average 2.5 times higher concentrations than those from the southern part of the watershed.

The most significant result indicated on this figure is that the irrigated portion of the watershed, which covers only 3 percent of the total watershed area, produces nearly 30 percent more TDS than the rangeland portion for the time period.

Data for the 1976-77 water year were analyzed separately because of the drought conditions which occurred at this time. Figure 4.a.4

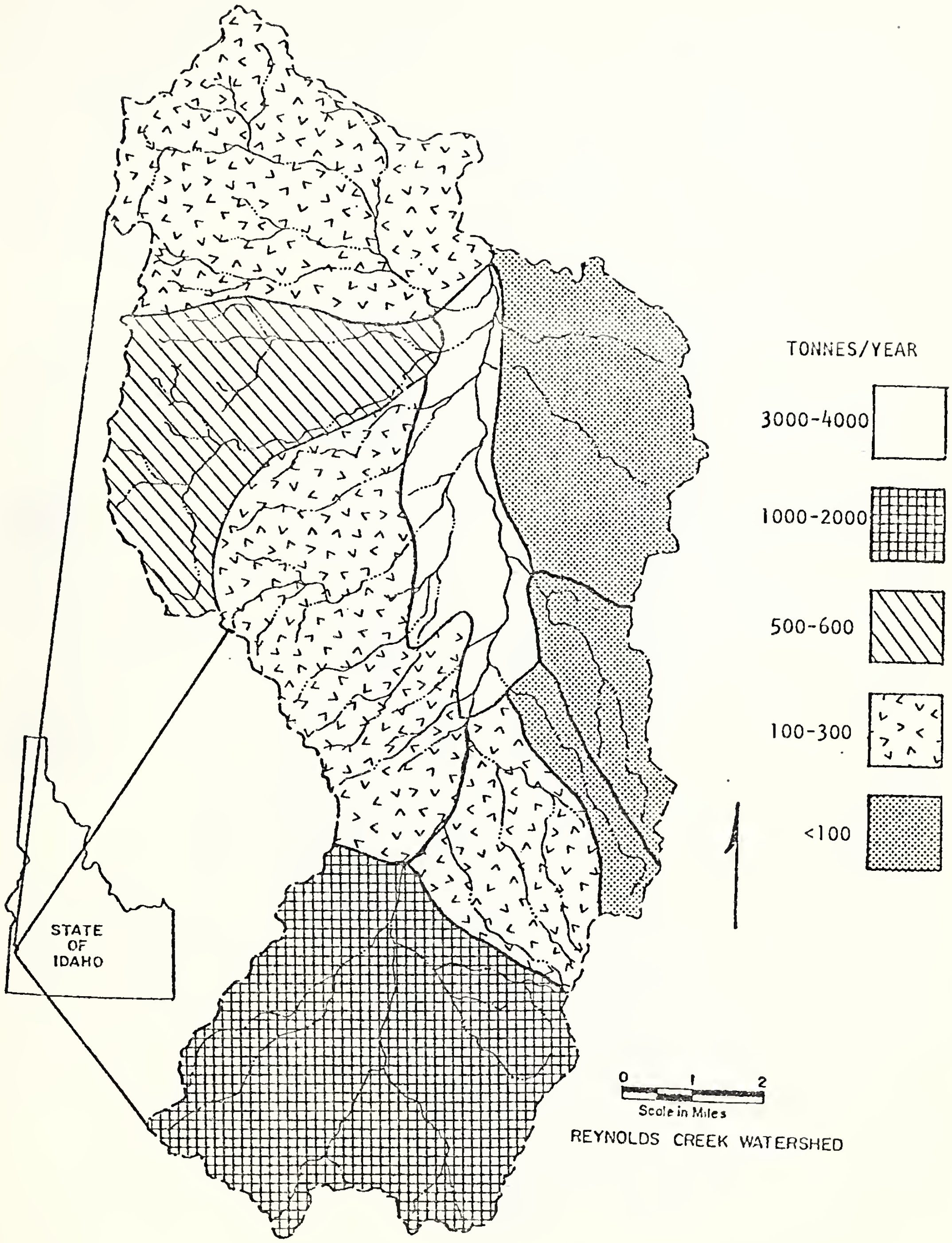


Figure 4.a.3.--Average volume of total dissolved solids (TDS) in tonnes per year, computed by water year, from October 1972 through September 1976.

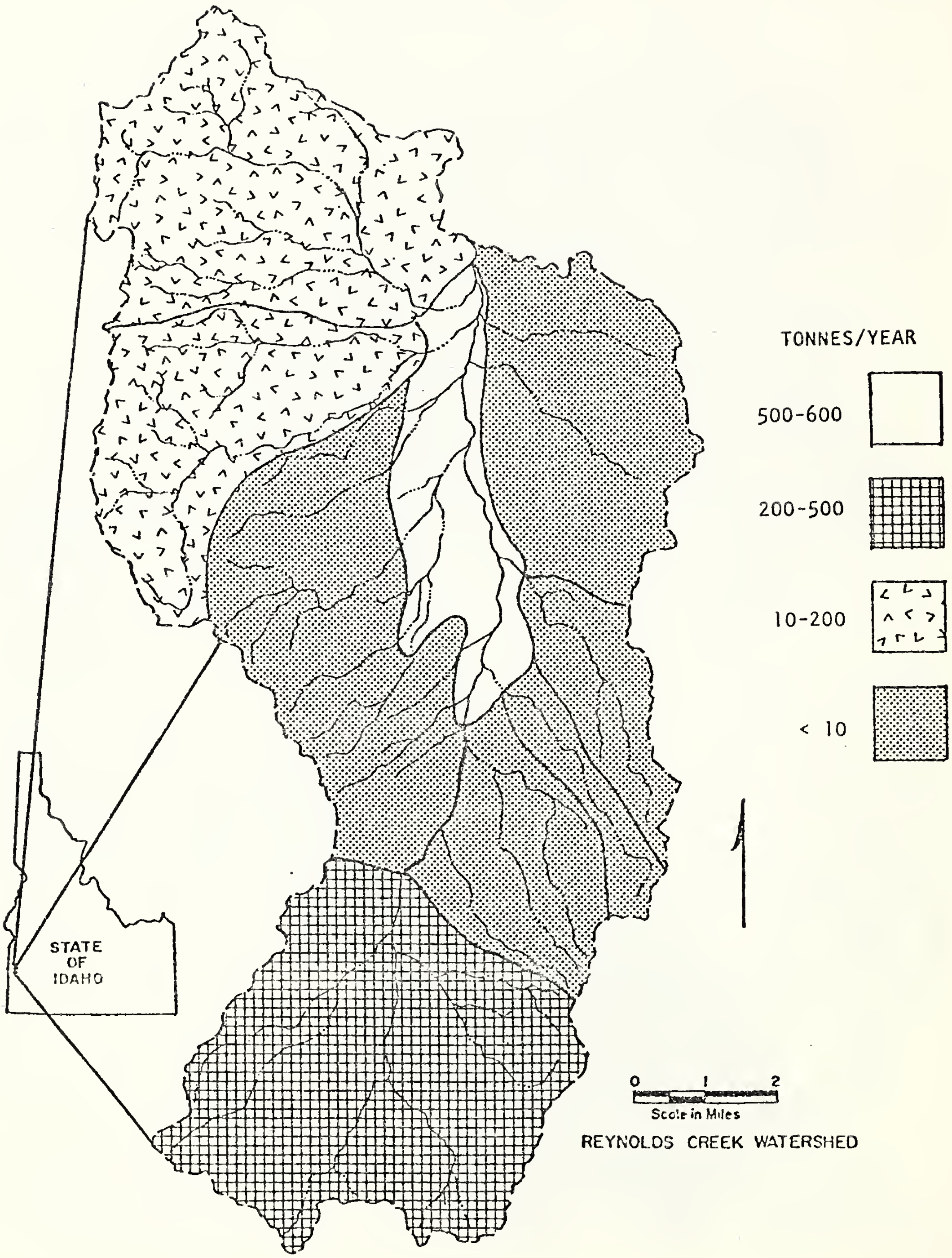


Figure 4.a.4.--Average volume of total dissolved solids (TDS) in tonnes per year, computed by water year, from October 1976 through September 1977.

gives the distribution of TDS volumes produced during the 1977 water year. Because of the lack of streamflow in much of the watershed, total TDS volumes were considerably less than the previous four years. However, the irrigated area was still the major producer of dissolved solids per unit area in respect to the rangeland portion of the watershed. A total of only 1110 tonnes of dissolved solids were removed from the total watershed in 1977, 46 percent of which were derived from the irrigated area. Table 4.a.3 gives the TDS production per unit area for the rangeland and irrigated portion of the watershed for the 1973 through 1976 water year and the 1977 water year.

Table 4.a.3.--Total dissolved solids per unit area.

	1973-1976 Water Years		1977 Water Year	
	Percent Watershed	Volume TDS (mt/ha)	Percent Watershed	Volume TDS (mt/ha)
Rangeland	97	0.09	97	0.03
Irrigated Land	3	4.96	3	0.73

EVALUATION OF RANGELAND MANAGEMENT PRACTICES FOR REDUCING NONPOINT SOURCE POLLUTION

Because of the severe drought conditions, no tests were run on this study. The initial plan was to monitor bacterial concentrations in a watershed in the deferred rotation management system where new, upland spring developments have been installed. The purpose of this study is to determine if this improved range management practice reduces cattle activity along streams, ultimately reducing fecal coliform concentration during the grazing season.

b. Boise Front Results

The FY 1977 work plan calls for the development of a water quality data base for the rest-rotation grazing management system on the Boise Front. For this purpose, four sampling sites were established and monitored during the year (refer to Introduction Figure 1). Even though no cattle were supposed to be in the alloted grazing area during the grazing season, a number of them strayed into the allotments. The area of study was supposed to be in rest at this initial time. The data given in Table 4.b.1 probably indicates the presence of stray cattle and also the presence of the large herd of deer which winter in the area. No attempt is made, with only one year's data, to make any conclusions.

Table 4.b.1.--Water quality characteristics, Boise Front Watershed sampling sites.

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		UPPER MAYNARD WEIR (322W54)			
pH	units	17	9.00	6.10	8.20
Conductivity	µmhos	17	2840.00	154.00	362.00
Dissolved solids	mg/1	17	1959.00	96.00	248.00
Calcium	mg/1	5	23.45	16.63	19.04
Magnesium	mg/1	5	3.40	2.92	3.14
Sodium	mg/1	5	12.18	8.97	10.35
Phosphorous	mg/1	5	0.12	0.02	0.05
Nitrate	mg/1	5	0.06	0.01	0.03
SiO_2	mg/1	5	36.10	26.0	30.18
Sodium adsorption ratio	ratio	5	0.62	0.53	0.58
Suspended solids	mg/1	16	18.00	1.00	8.00
Total coliform	cts/100 ml	18	505	0	160
Fecal coliform	cts/100 ml	18	496	0	75
Fecal strep	cts/100 ml	18	1800	0	229
COD	cts/100 ml	18	16.40	0	6.30
BOD	cts/100 ml	14	4.00	0	1.69
DO	cts/100 ml	17	12.00	5.5	8.71
		HIGHLAND VALLEY WEIR (419W56)			
pH	units	24	8.38	7.05	7.69
Conductivity	µmhos	25	2356.00	135.00	362.00
Dissolved solids	mg/1	25	1626.00	104.00	249.00
Calcium	mg/1	5	17.40	13.20	15.16
Magnesium	mg/1	5	4.50	1.20	3.74
Sodium	mg/1	5	9.40	7.80	8.46
Phosphorous	mg/1	5	0.23	0.07	0.12
Nitrate	mg/1	5	0.98	0.39	0.67
SiO_2	mg/1	5	37.80	26.50	31.10
Sodium adsorption ratio	ratio	5	0.53	0.47	0.50
Suspended solids	mg/1	23	45.00	3.00	18.00
Total coliform	cts/100 ml	25	9900	14	1660
Fecal coliform	cts/100 ml	25	2200	0	457
Fecal strep	cts/100 ml	26	27000	28	4952
COD	mg/1	26	15.00	0	8.00
BOD	mg/1	21	3.00	0	2.00
DO	mg/1	25	11.00	9.00	7.00
		CAMP CREEK (336W12)			
Total coliform	cts/100 ml	10	1450	5	221
Fecal coliform	cts/100 ml	11	1406	0	176
Fecal strep	cts/100 ml	11	760	5	202
COD	mg/1	4	8.10	6.60	7.10
BOD	mg/1	0	--	--	--
DO	mg/1	10	10.50	7.50	9.00
		LOWER MAYNARD (328W5)			
Total coliform	cts/100 ml	11	242	0	70
Fecal coliform	cts/100 ml	12	85	0	14
Fecal strep	cts/100 ml	12	1010	10	348
COD	mg/1	10	9.80	5.40	7.60
BOD	mg/1	7	2.00	0.50	1.40
DO	mg/1	12	12.00	6.00	8.90

c. Rangeland Wintering Operations

This project was initiated in November 1976 in cooperation with the University of Idaho. A final agreement has been made with a rancher for use of his land, and approximately 4 ha of cattle wintering area adjacent to Reynolds Creek in Owyhee County have been developed into six experimental plots. The plots consist of three stocking rate treatments with two replications of each. The treatments are (1) no cattle, (2) 12 head/ha, and (3) 37 head/ha. The experimental area has been mapped and the plots established with appropriate fencing and drainage dikes. A well has been drilled, and electrically heated stock watering tanks have been installed at the sites. Runoff water measuring weirs have also been built. Cattle have been turned into the plots and data collection involving runoff during the irrigation season will begin in late spring or early summer of 1978, depending on the rancher's irrigation needs. While the plots are without cattle they are used for a hay crop. A computer program has been developed to maintain data files and process data for later analysis. Water samples will be analyzed for bacterial and chemical nutrient indicators. Rates and amounts of runoff and sediment will also be measured. The effects of cattle concentration on hay yield will also be observed. Evaluation of the contribution of these wintering operations to the water quality of Reynolds Creek will put in proper perspective the impact of rangeland practices on water quality.

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A P P E N D I X

APPENDIX I

1977 DROUGHT REPORT

The drought that was experienced in the Pacific Northwest during the 1977 water year aroused a great deal of community, state, and national interest in present and future water supplies and their impact on agricultural and urban life-styles and economic well being. Since the Reynolds Creek Experimental Watershed has, since 1961, observed and documented hydrologic conditions, it was possible to compare average conditions with the 1977 conditions. Various hydrologic variables, such as precipitation and streamflow, are discussed in the following sections. Figure 1 is a map of the watershed showing the locations of the hydrologic variable measurement sites.

PRECIPITATION

Precipitation for water year 1977 was at near record lows at all elevations on the Reynolds Creek Watershed (Figure 2) primarily due to the low precipitation amounts during the winter months of November 1976 through January 1977. Precipitation during these months generally accounts for 40 percent or more of the water year total. The normal amount for this period varies from 4.28 inches at gage 076X59 to 21.52 at gage 176X07 (see Location Map). During the 1977 water year, the precipitation for the 3-month period varied from 0.68 inches at 076X59 to 2.69 inches at gage 176X07. February and March precipitation was about 77 percent of normal at all elevations and April was the driest April on record. Accumulated precipitation, October 1, 1976 through April 30, 1977, was only 31 percent of normal and was the lowest of record at the three locations.

May precipitation was about twice normal, and June precipitation was about normal, which improved range conditions, resulting in above average forage production at the higher elevations.

July, August and September precipitation was at or above normal and maintained favorable range conditions at the higher elevations. The total during these three months, however, did not increase streamflow. The total precipitation for the 1977 water year was 7.32 to 21.12 inches and averaged about 55 percent of average.

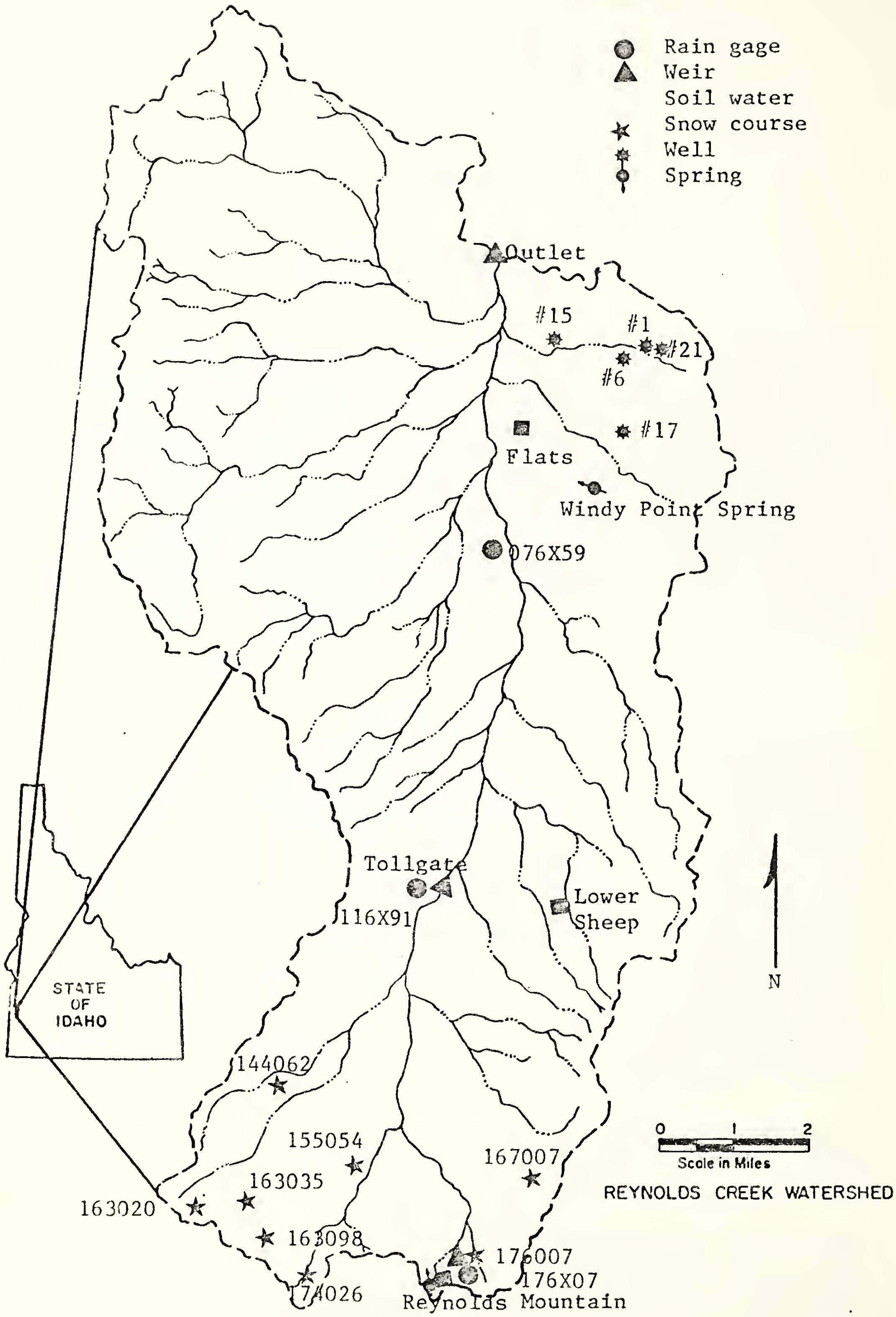


Figure 1.--Locations of hydrologic variable measurement sites.

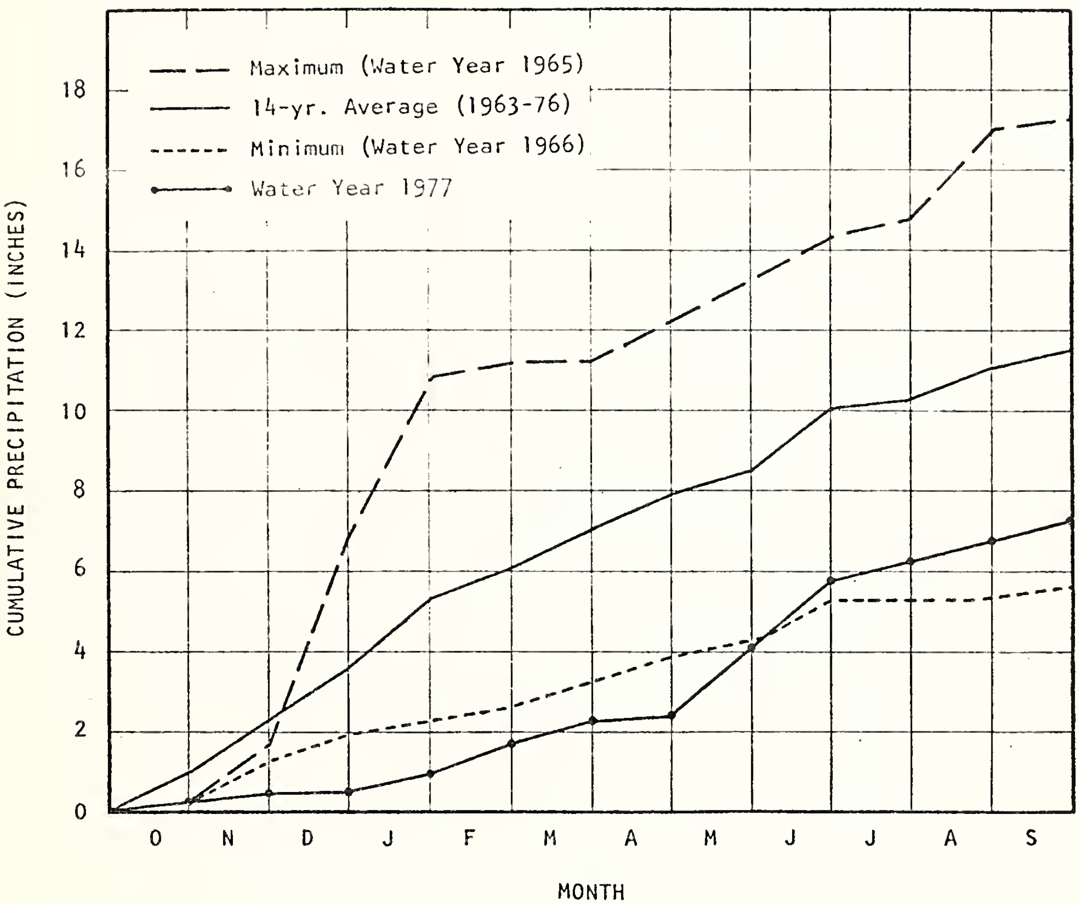


Figure 2a.--Cumulative precipitation at Reynolds Creek Watershed rain gage number 076X59, elevation 3965 feet.

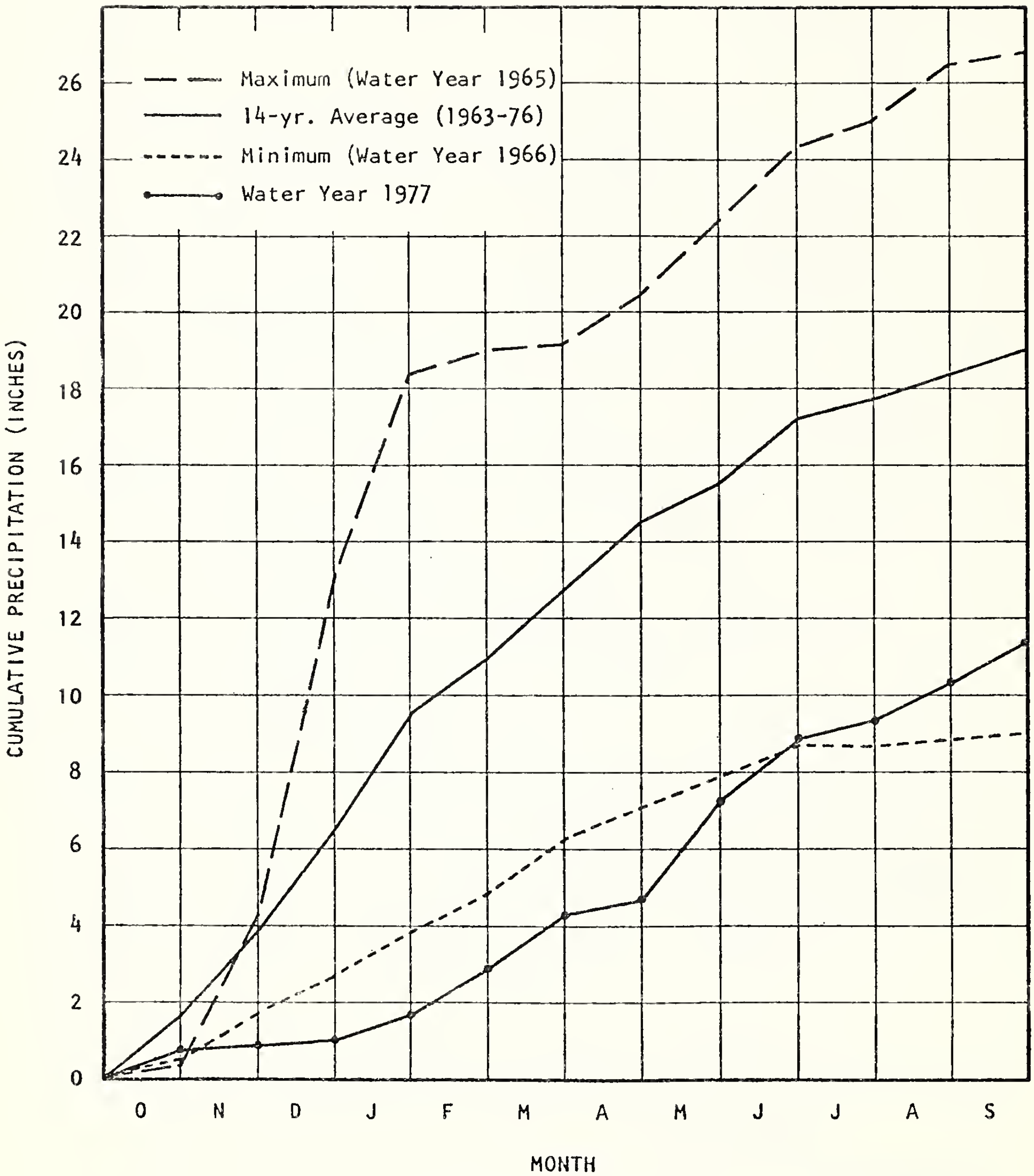


Figure 2b.--Cumulative precipitation at Reynolds Creek Watershed rain gage number 116X91, elevation 4760 feet.

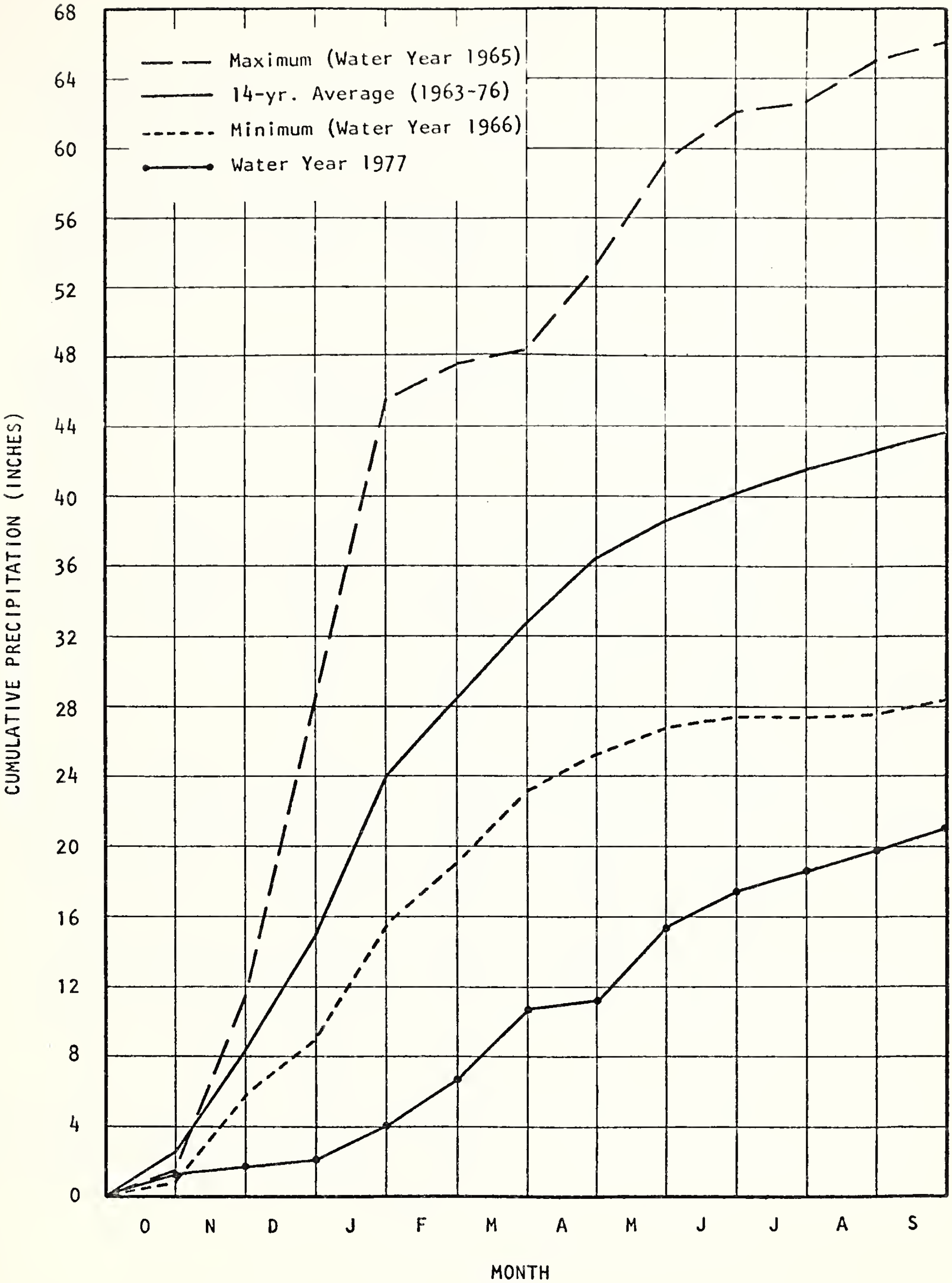


Figure 2c.--Cumulative precipitation at Reynolds Creek Watershed rain gage number 176X07, elevation 6760 feet.

STREAMFLOW

Streamflow at the beginning of the water year, October 1976, was about average at Reynolds Creek runoff stations. Then during the following winter months streamflow decreased, compared with the average of record, to levels lower than previously recorded (Figure 3). The streamflow from the East Reynolds Mountain watershed (see location map) was zero during August and September, the first time this spring-fed stream has been dry since records began in 1961.

Total water yields were 10.8, 15.1, and 16.0 percent of the previous yearly average of record at the Reynolds Outlet, Reynolds Tollgate, and East Reynolds Mountain stations, respectively. Water yields were only about 50 percent of yearly totals in 1968, the previous record low.

The March through July water supply prediction made March 1 for the Tollgate runoff station was 1.06 inches. This was only 13 percent of normal. Input to the prediction was snow course data in the contributing watershed (see Appendix II). Actual measured runoff during the forecast period was 1.10 inches.

SOIL WATER

At low elevation locations, for example Flats at 3885 feet, soil water was below normal during March and April, 1977 (Table 1). The heavy precipitation during May and June then increased soil water to above average during the last part of May and June. Soil water was about average from July 1 through September.

Soil water at the mid-elevation site (lower Sheep, 5410 feet) was about 15 percent below average during late winter and spring and then soil water increased to above average during June and stayed above through September.

At Reynolds Mountain, elevation 6760 feet, soil water was also somewhat below average during late winter and early spring, but increased to above average during May and June. After the heavy precipitation in early summer, soil water stayed above average through September.

SNOW COURSES

Reynolds Creek runoff, March 1st through July 31st, is highly dependent on the amount of water stored in the snow at the higher elevations. Fifteen years of water equivalent data have been collected on snow courses located in the upper 21-square mile Tollgate drainage, the major snow accumulation area on Reynolds

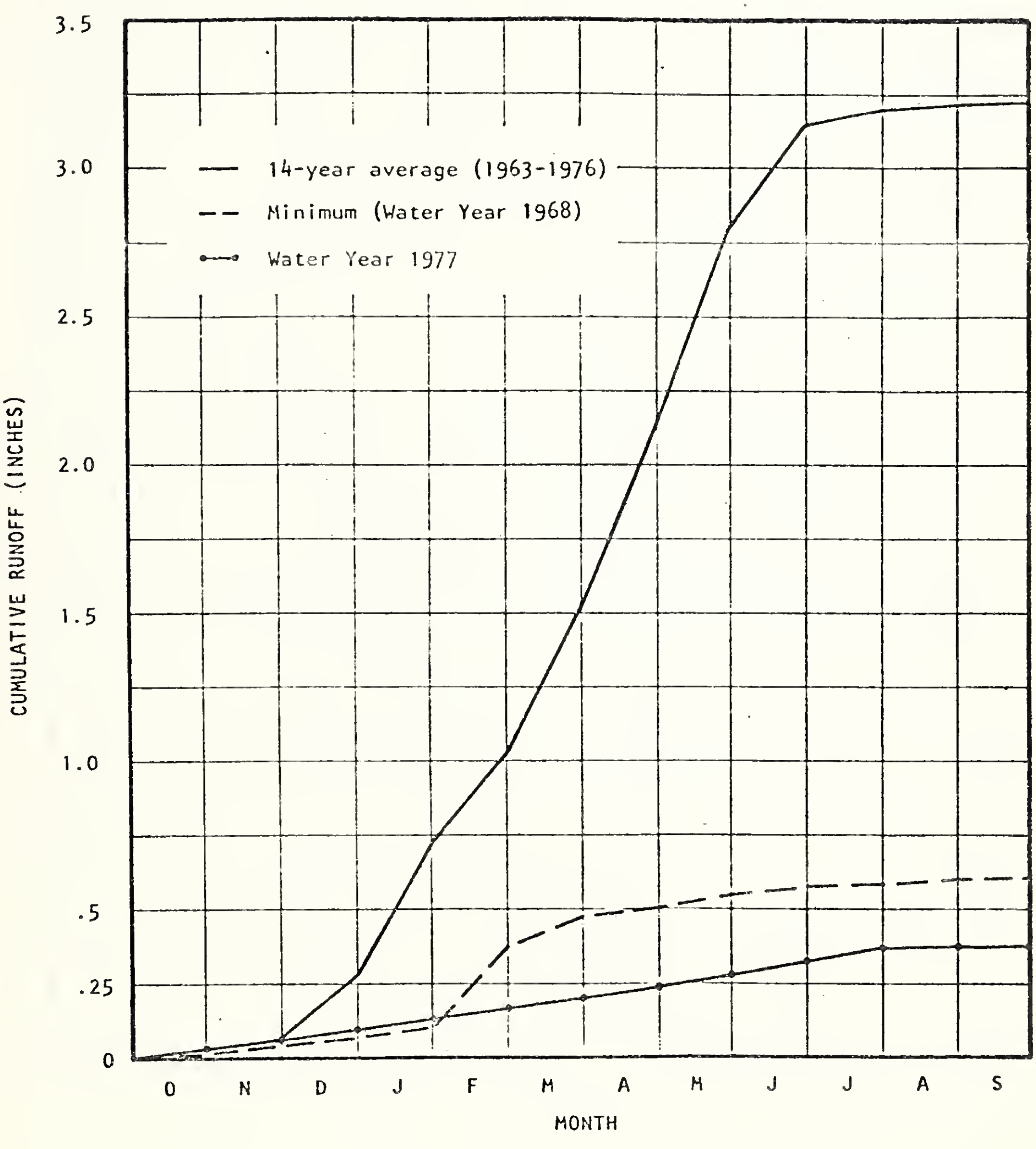


Figure 3a.--Cumulative runoff measured at the Outlet Weir, Reynolds Creek Watershed.

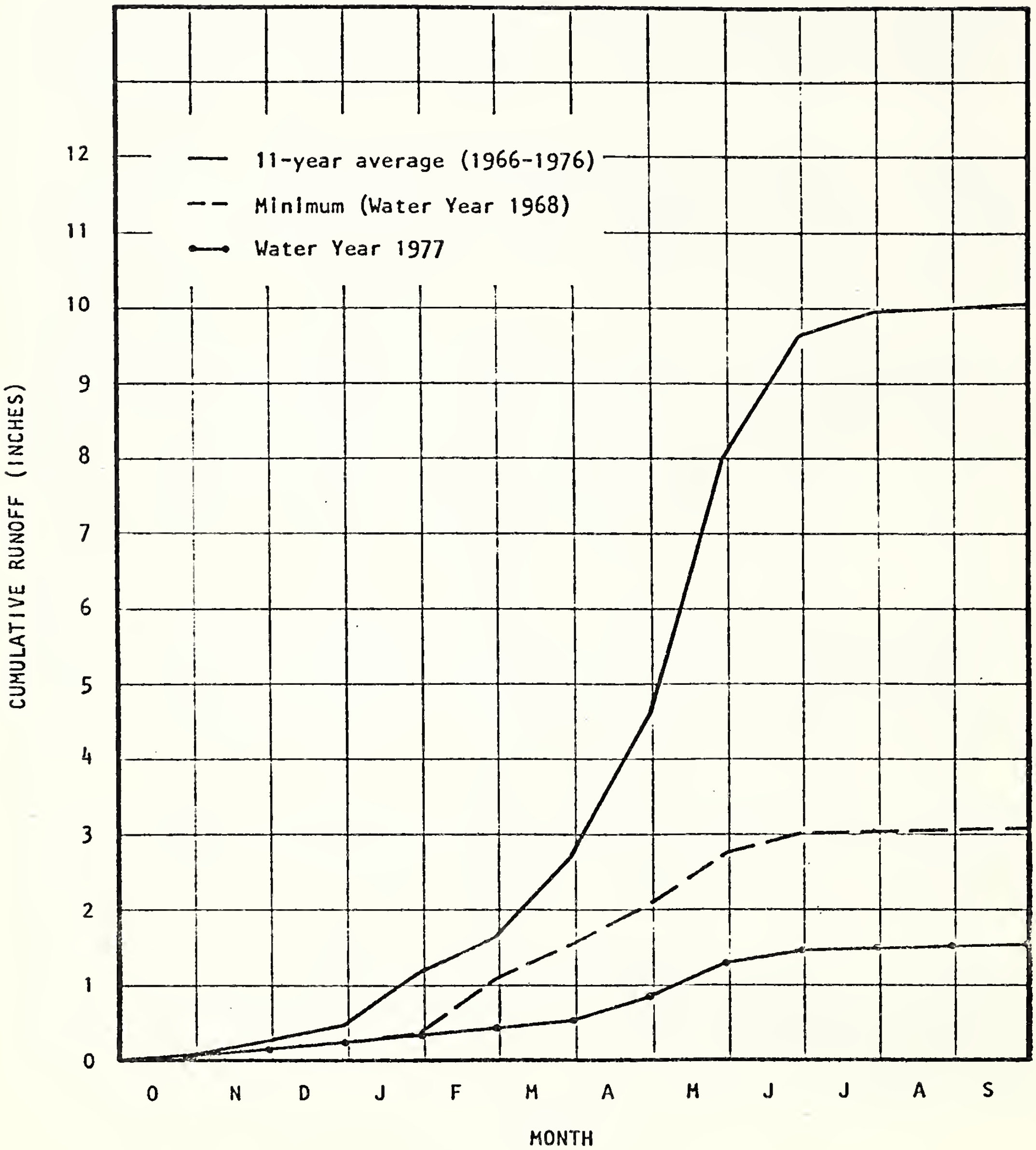


Figure 3b.--Cumulative runoff measured at Tollgate Weir, Reynolds Creek Watershed.

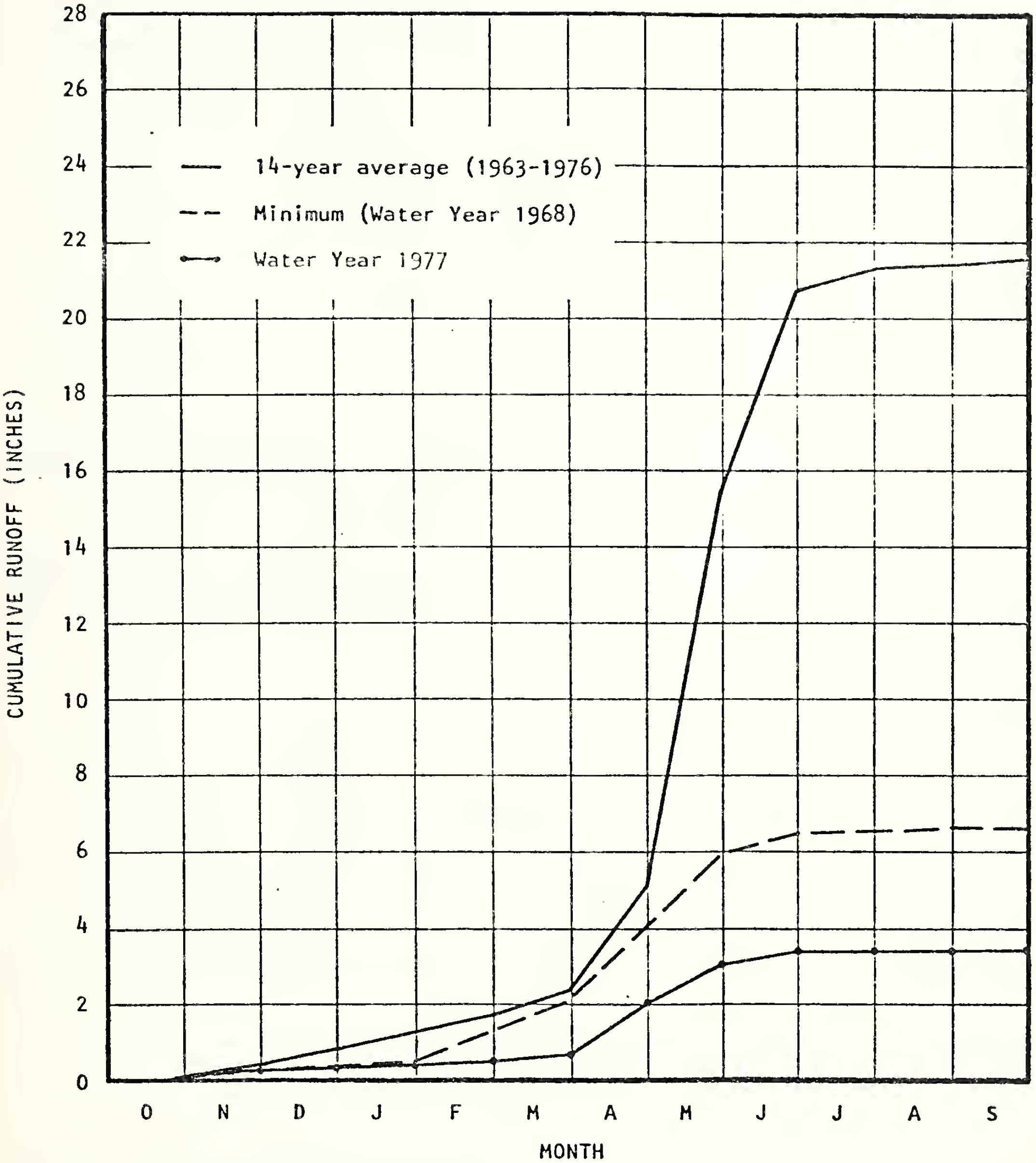


Figure 3c.--Cumulative runoff measured at East Reynolds Mountain Weir, Reynolds Creek Watershed.

Table 1.--Soil water in a 3.5-foot profile for three Reynolds Creek Watershed locations, taken at one measuring point.

Date		Flats	Lower Sheep	Reynolds Mountain
		inches		
March 1[1]	1977	6.0	10.1	16.9
	4-yr. avg.[2]	6.8	12.4	17.2
April 1	1977	5.2	9.8	17.0
	4-yr. avg.	6.5	11.4	17.8
May 1	1977	5.7	9.8	19.3
	4-yr. avg.	5.7	11.4	17.9
June 1	1977	6.1	9.8	18.3
	4-yr. avg.	5.3	10.5	17.5
July 1	1977	5.3	10.0	18.4
	4-yr. avg.	5.2	9.1	15.0
August 1	1977	4.9	9.5	14.8
	4-yr. avg.	4.7	8.2	13.1
September 1	1977	4.8	8.2	13.7
	4-yr. avg.	4.8	7.9	11.2
October 1	1977	4.6	9.0	13.5
	4-yr. avg.	4.5	7.4	11.9

1/ Soil water measurements were obtained on the watershed every 2 weeks; therefore, the soil water values are within 1 week of the date listed.

2/ The 4-year average is for the years 1973 through 1976.

Creek. Eleven years of runoff data from this drainage indicate that during the period of March 1 through July 31, on the average, 80 percent of the annual total runoff occurs. This demonstrates the importance of the water stored in the winter snowpack.

The water equivalent of the snowpack is determined at each of eight snow courses every two weeks, starting in mid-December and continuing through the snow season. Table 2 shows that the maximum snow accumulation on April 1, 1977, was only 38 percent of the average water content. Nearly all of this snow was melted by May 1, compared to a normal year when snowmelt continues until late June. Figure 4 shows the water equivalent for the 1977 water year and how it compared with the maximum, minimum and 15-year average water equivalent at snow course 176007 (see location map). This figure also shows that there was only about one-half as much water stored at this location as in the previous low year, 1968. The maximum accumulation was on April 1 compared to the normal year of late April. April was a very dry month and the accumulation decreased all during the month.

Based on the maximum snow accumulation, 1.06 inches of runoff was forecast for Tollgate for the March through July period. There were 1.10 inches of runoff measured at Tollgate, which was the lowest since records started in 1966 and only 13 percent of the past 11-year average. The forecasted and measured runoff was within 4 percent, which indicates that the snowmelt-runoff prediction model estimates runoff very well.

GROUNDWATER TRENDS

Records from five wells and two springs have been selected to illustrate recent trends in groundwater storage in the major aquifer system on the Reynolds Creek Watershed. The length of record varies among the sites, but a continuous record from 1961 through 1976 is available for Well No. 1 and is summarized in Figure 5. Continuous readings were started again in March 1977. Water levels from Well No. 1 typify the general recharge and storage characteristics of the basalt aquifer system. Water level trends, based upon June 1st readings for each year of the history of each well, at four other sites are given in Figure 5. The last major recharge event to the aquifer system was in 1969, which is noted on Figure 5. Well No. 15 is the only site showing a positive elevation change, and this is the result of construction of a storage reservoir close by, which locally recharges the system in this locality. Water level readings from Well No. 15 show a continuous decline since 1974, up to April 1977 when the reservoir was filled to capacity, causing some recharge to aquifer storage in the vicinity of Well No. 15.

Table 2.--1977 snowpack water equivalent.

Snow Course by Ident. Number	March 15			April 1			April 15			May 1		
	Snow-pack Water Equiv-alent	14-yr. Average Water Equiv-alent	Water Equiv-alent as % of Avg.	Snow-pack Water Equiv-alent	14-yr. Average Water Equiv-alent	Water Equiv-alent as % of Avg.	Snow-pack Water Equiv-alent	14-yr. Average Water Equiv-alent	Water Equiv-alent as % of Avg.	Snow-pack Water Equiv-alent	14-yr. Average Water Equiv-alent	Water Equiv-alent as % of Avg.
	------------ inches ------------											
144062	5.4	13.6	40	6.5	12.2	53	0.0	8.7	00	0.0	0.0	--
155054	3.2	12.0	27	2.5	10.2	25	0.0	7.0	00	0.0	0.0	--
163020	10.3	26.0	40	12.0	29.3	41	12.5	31.8	39	8.9	23.4	38
163035	8.4	26.1	32	10.6	30.2	35	7.1	30.9	23	0.0	28.4	00
163098	9.4	25.6	37	10.2	29.0	35	7.7	31.3	25	0.0	25.9	00
167007	4.1	10.5	39	4.5	11.0	41	0.0	8.4	00	0.0	4.9	00
174026	9.6	23.8	40	10.2	26.8	38	8.5	28.9	29	0.0	25.2	00
176007	6.3	21.0	30	8.7	22.9	38	4.9	24.0	20	0.0	20.7	00

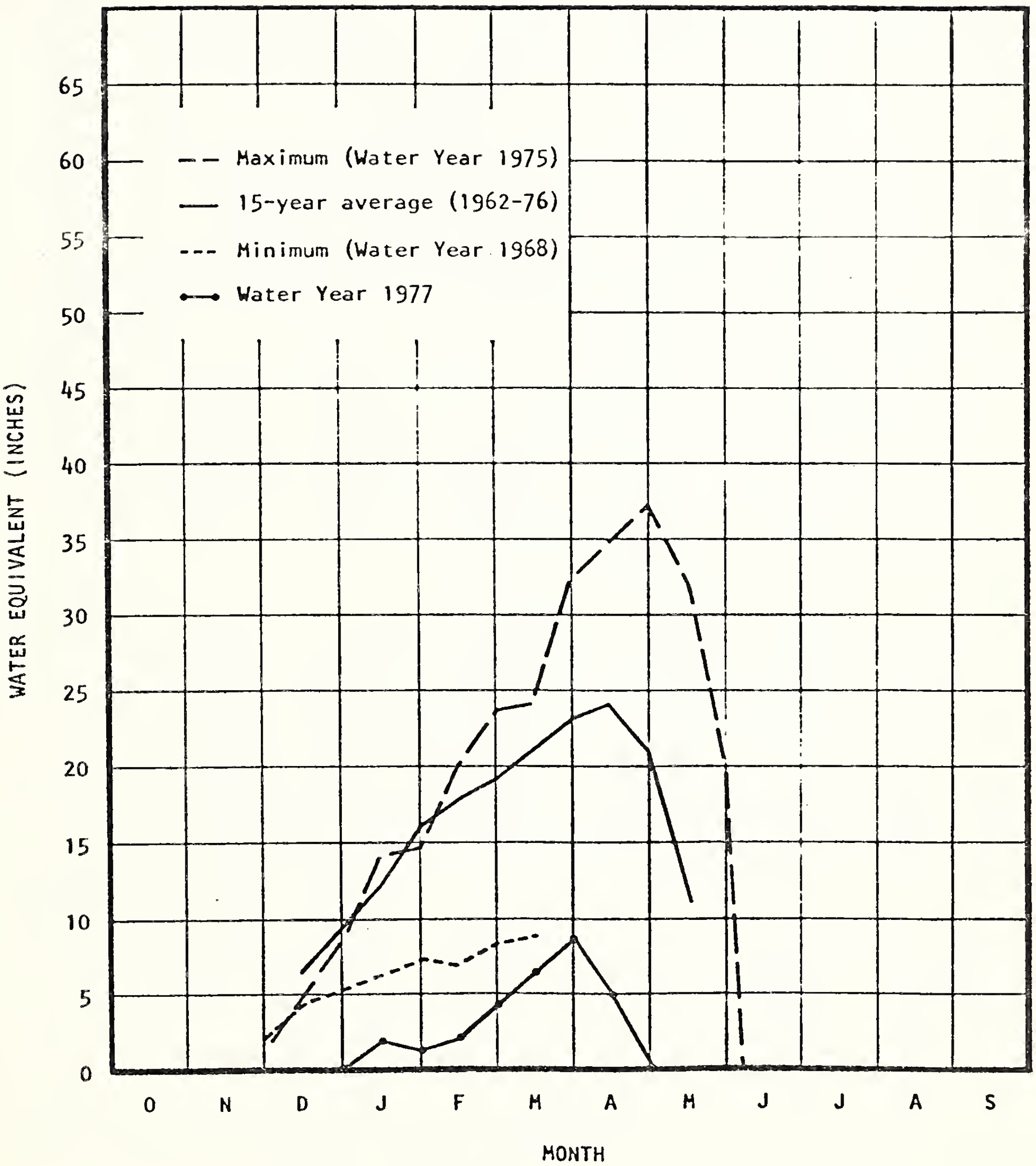
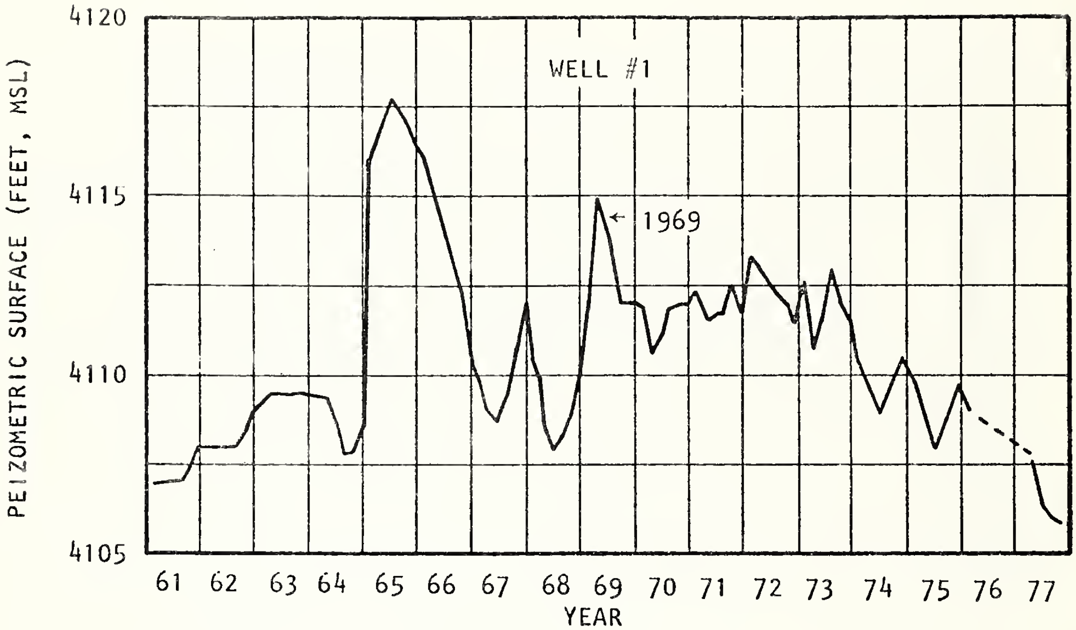


Figure 4.--Snow water equivalent measured at snow course 176007, Reynolds Creek Watershed.



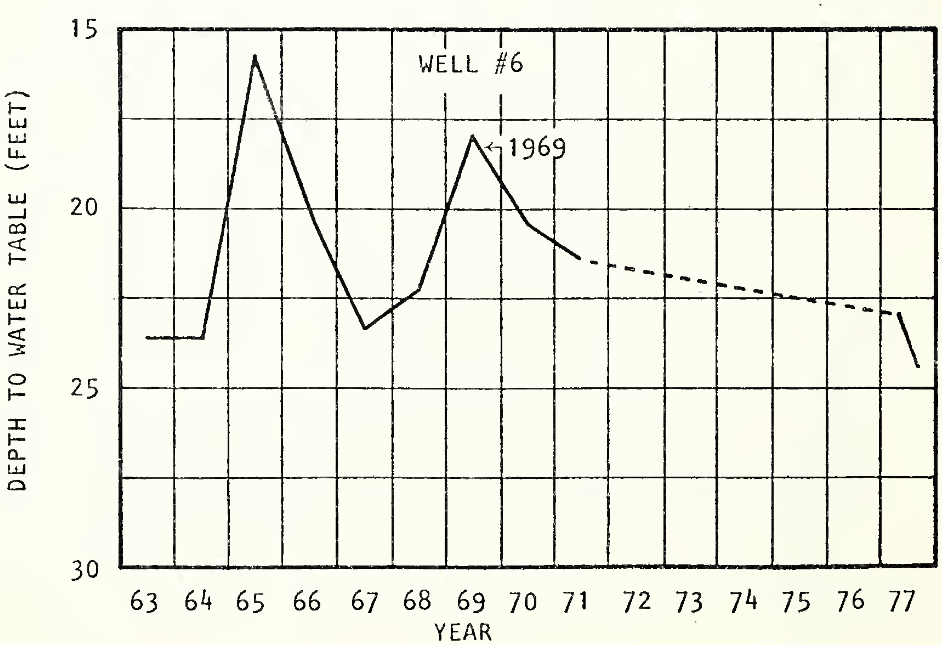
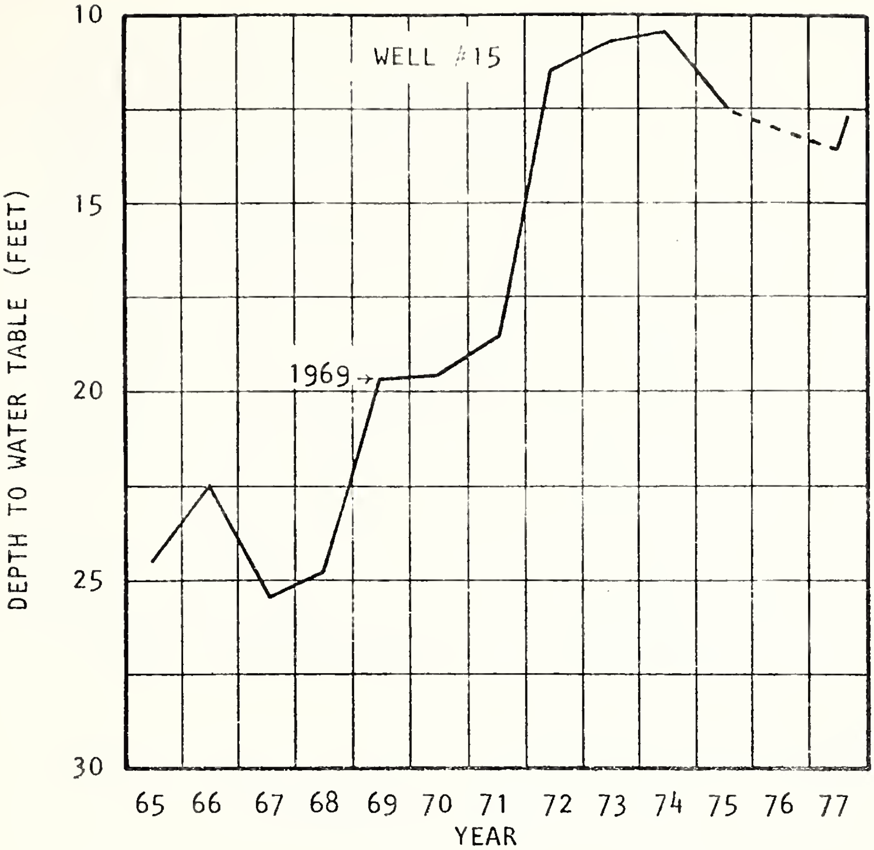


Figure 5a.--Peizometric surface depth record for Well No. 1 and depth to water table record for Well No. 6, Reynolds Creek Watershed.



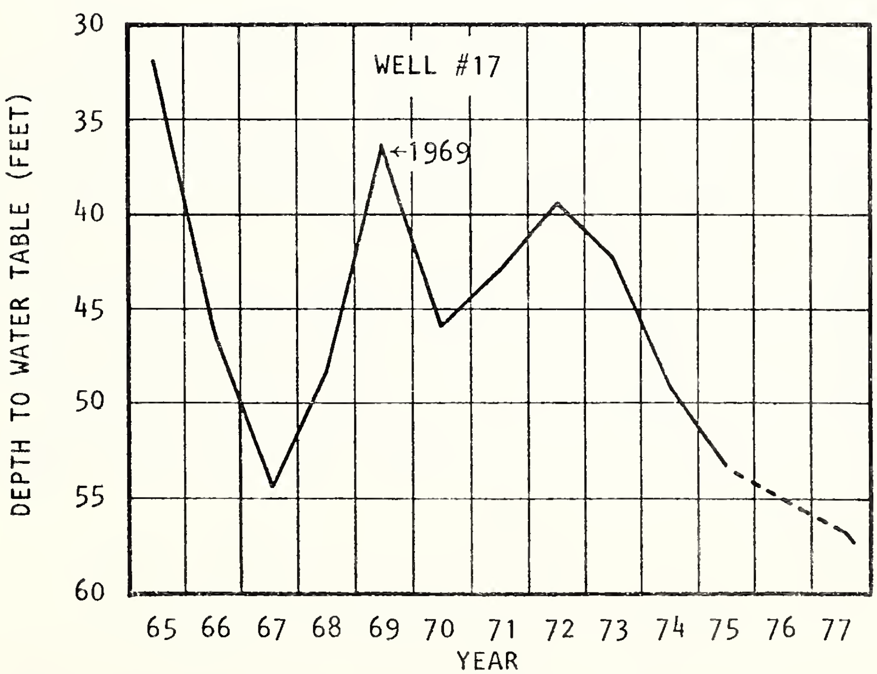


Figure 5b.--Depth to water table record for Well No. 15 and Well No. 17, Reynolds Creek Watershed.

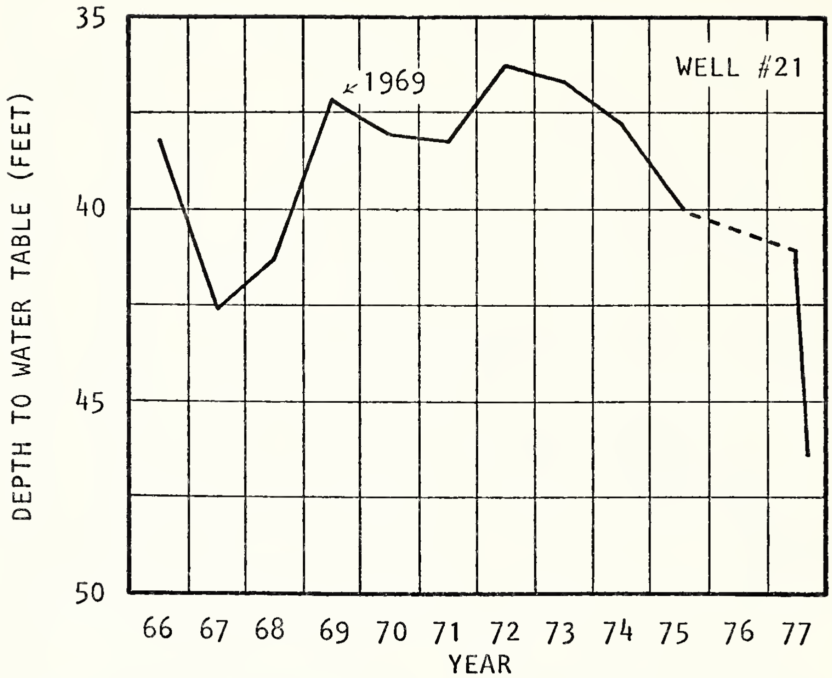


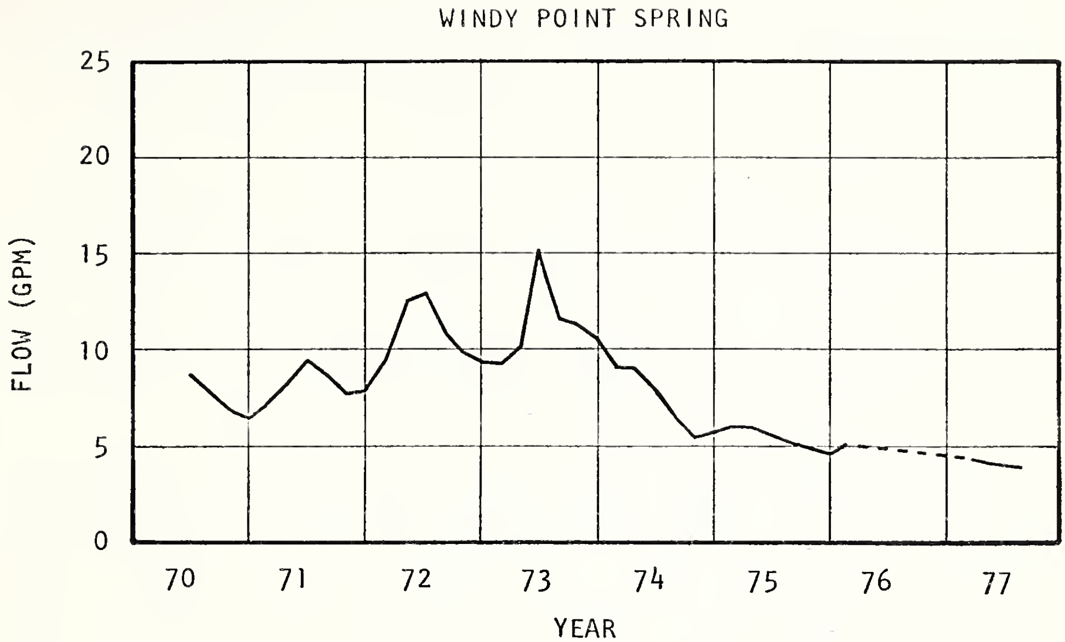
Figure 5c.--Depth to water table record for Well No. 21, Reynolds Creek Watershed.

Windy Point Spring is a local groundwater discharge site at which a V-notch weir has been constructed to give continuous flow measurements. The flow is from the same aquifer system penetrated by the previously described wells. As shown in Figure 6, the general downward trend of groundwater storage prevails at the Windy Point Spring site.

The Reynolds Mountain Spring well site, located at 6800 feet elevation, where snowmelt recharges the aquifer, shows a sharp decline in storage. Figure 6 shows the annual spring recharge at this site and the subsequent downward trend in discharge from storage. Recharge from snowmelt in 1977 was only slightly over 50 percent of the 5-year average at this site, showing the result of the sparse snow accumulation above this site.

Groundwater on Reynolds Creek Watershed is important for three reasons:

(1) Base flow for Reynolds Creek relies almost entirely on discharge from the basalt aquifer system. Lack of significant recharge seriously curtails streamflow during the late summer months. As the records show, groundwater storage has declined during



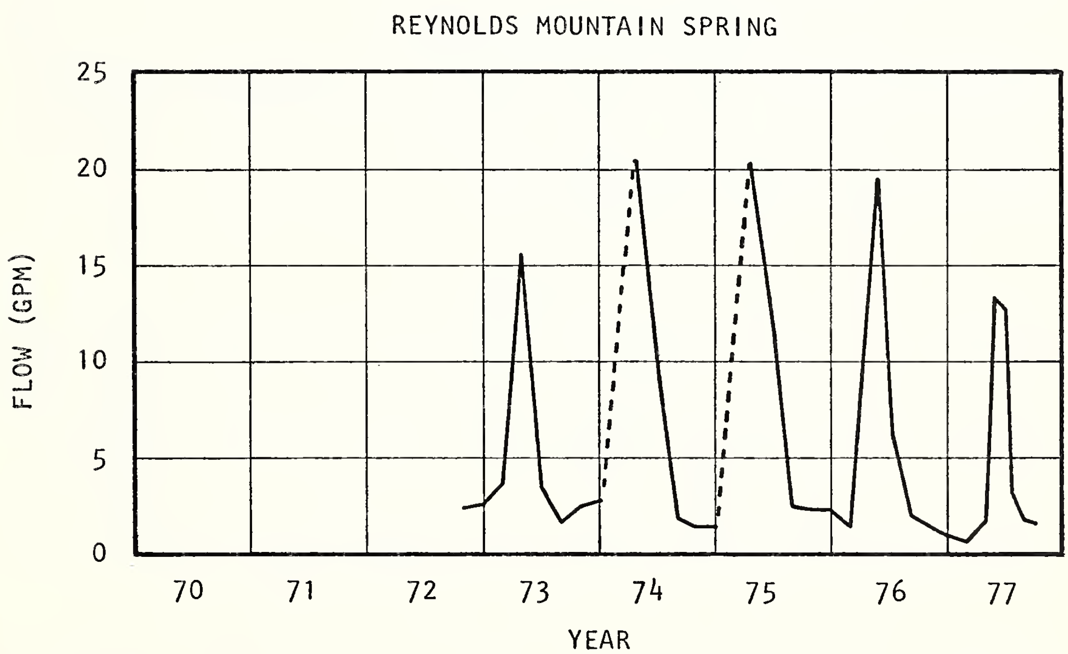


Figure 6.--Spring flow record for Windy Point Spring and Reynolds Mountain Spring, Reynolds Creek Watershed.

the past several years, making 1977 a very critical year when needed recharge did not occur and levels fell even more. The above-normal rains that fell in May 1977 were insufficient to recharge the groundwater system and base flow continued to decrease through the end of the water year.

(2) Water from the aquifer in the vicinity of Well No. 1 is pumped for 8 to 10 weeks each spring and distributed to stock watering tanks over several sections of rangeland. This is the only source of stock water in this area. If groundwater storage continues to decline without significant recharge, there may be insufficient water available for livestock watering on this portion of range during the 1978 grazing season. The September 30, 1977, water levels in this area are the lowest in the 17-year record.

(3) Both the Reynolds Mountain and Windy Point discharge springs indicate serious downward trends in storage. Further depletion in storage without recharge could seriously curtail flow in either of these springs. Both springs furnish stock water for many sections of rangeland, and loss of these water sources could remove these areas from local rangeland livestock operations. As of September 30, 1977, Windy Point spring is recording the lowest flow for the 8-year record. Reynolds Mountain spring has yet to reach the lowest recorded flow.

The sites used in this report are typical of the entire groundwater network on the Reynolds Creek Watershed as of September 30, 1977. Without a significant period of recharge to the aquifer system, aquifer storage could be depleted to such a level as to seriously diminish base flow to Reynolds Creek.

SUMMARY

Precipitation for water year 1977 was at or near record lows at all elevations on the Reynolds Creek Watershed. The primary reason being the record low precipitation amounts during the winter months of November through January. May and June precipitation was above average, which improved range conditions especially at higher elevations. The total precipitation for the water year was about 2 inches above the 1968 dry year at the low and mid-elevations, but 7 inches below the previous low at the high elevations.

The water year total was 36 percent below the average at the low and mid-elevations and 50 percent below average at the high elevations.

Total water yields were 10.8, 15.1 and 16.0 percent of the yearly average at Reynolds Outlet, Reynolds Tollgate and East Reynolds Mountain stations, respectively. Water yields were about 50 percent of the yearly totals in 1968 when the previous record low streamflows were recorded.

Soil water was below average during the early spring, but came up to average during the heavy May and June rains and stayed at or above average throughout the rest of the year.

The maximum water stored in the snowpack was on April 1 and was only 38 percent of the average. Based on the snow accumulation, 1.06 inches of runoff was forecast for Tollgate drainage for the March through July period. There were 1.10 inches of runoff measured from the Tollgate drainage showing that the forecast was within 4 percent.

Well and spring information shows that the groundwater levels have been declining since 1969. The dry winter conditions during 1977 lead to the lowest groundwater levels on record.

Because of the drought condition, a portion of Reynolds Creek and related springs dried up causing reduced irrigation, curtailment of some livestock watering and reduction of a lively native trout population along the upper portion of the stream.

APPENDIX II

REYNOLDS CREEK 1977 WATER SUPPLY FORECAST

An optimizing technique for determining the alpha and beta coefficients of a linear forecast model was developed for the Tollgate drainage of Reynolds Creek. The model was originally developed to predict the runoff volume through Tollgate weir for the March through July period, during which time 80 percent of the total yearly flow occurs. The technique uses the snowpack water equivalent on March 1st, March 15th and at maximum accumulation from 7 snow courses in the Tollgate drainage and runoff volume as input variables. The optimization program[1/] used initial estimates of model parameters which were obtained by constructing a Thiessen network for the basin thus producing a percentage of the total basin for each parameter. The model was first developed with 7 years data, 1966-72, and updated each year as data became available and currently uses an 11-year data base.

Tables 1 and 2 show observed runoff volumes and predicted runoff volumes from March 15th and maximum accumulation forecast periods for the past 5 years with the percent error listed for each forecast. This procedure was further tested by using accumulated actual precipitation[2/] from 7 precipitation gages within the Tollgate drainage. Actual precipitation was accumulated for the time periods October through February, October through March, November through February, and November through March as input to the optimization program. Table 3 lists the statistics produced for each time period using only accumulated precipitation. The initial estimates of the beta coefficients were the Thiessen values for the snow course plot. The third method tested used a combination of accumulated precipitation and snow water equivalent to predict runoff volume. Linear regression analysis was used to relate

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[1/] Green, Ralph F. 1970. Optimization by the pattern search method. Res. Paper No. 7, Tenn. Valley Authority, Knoxville.

[2/] Hamon, W. R. 1972. Computing actual precipitation. Proc. World Met. Organization. Dist. of Precip. in Mountainous Areas. Geilo, Norway, Vol. 1: 159-175.

Table 1.--Observed and predicted March through July runoff volume at Tollgate Weir using March 15 snow water equivalent.

Date	Observed Flow	Predicted Flow	Error
	------- *inches*	--------	*percent*
1973	4.663	2.5632	45.0
1974	10.997	11.09	0.8
1975	12.360	9.5804	22.5
1976	8.4686	8.4584	0.1
1977	1.0995	1.7659	60.6

Table 2.--Observed and predicted March through July runoff volume at Tollgate Weir using maximum snow water equivalent.

Date	Observed Flow	Predicted Flow	Error
	------- *inches*	--------	*percent*
1973	4.663	3.58	23.2
1974	10.997	10.413	5.3
1975	12.360	12.4454	0.7
1976	8.4686	7.7093	9.0
1977	1.0995	1.0558	4.0

Table 3.--Statistics from the relationship between accumulated precipitation for given time periods at seven precipitation gage sites (144X62, 145X37, 155X07, 163X20, 167X07, 174X14, 176X07), and March through July runoff volume.

	Accumulated Precipitation			
	Oct.-Feb.	Oct.-Mar.	Nov.-Feb.	Nov.-Mar.
correlation coefficient	.9018	.9559	.9456	.9588
standard deviation	3.6162	2.4576	2.7218	2.3765
coefficient of variance	.4282	.2910	.3223	.2814
standard error of estimate	1.6172	1.0991	1.2172	1.0628
round converged	18	25	46	14
times model was evaluated	257	352	583	195

accumulated precipitation and snow water equivalent to runoff to determine which sites would have the highest correlation with runoff volume. Thus, this procedure produced combinations of sites for initial optimization runs. Table 4 displays the correlation coefficients between accumulated actual precipitation for the time periods indicated and March through July runoff. Table 5 displays the correlation coefficients between snow water equivalent on March 1st, March 15th, and seasonal maximum accumulation and March through July runoff volume at Tollgate. As the tables indicate, the best results were obtained by substituting precipitation site number 176X07 for snow course number 167007 in the March 1st forecast formula and substituting precipitation site number 176X07 and number 163X20 for snow course number 155054 and number 167007 in the March 15th and maximum accumulation forecast formulas. Table 6 lists the statistics produced by the best combination of precipitation sites and snow course water equivalent values.

Table 4.--Correlation coefficients indicating the relationship between accumulated precipitation for given time periods as compared to March through July runoff volume at Tollgate Weir (10-year data).

Rain Gage Ident. Number	Accumulated Precipitation			
	Oct.-Feb.	Oct.-Mar.	Nov.-Feb.	Nov.-Mar.
144X62	.744	.821	.716	.821
145X37	.780	.886	.742	.885
155X07	.823	.896	.805	.898
163X20	.859	.912	.836	.911
167X07	.834	.873	.730	.818
174X17	.791	.868	.737	.838
176X07	.949	.954	.953	.962

Of all the combinations tested, the original method of using only snow water equivalent values of the 7 snow courses provided the best results as indicated in Tables 7, 8 and 9, which give statistics for optimization program based on 9-, 10- and 11-year data base.

Table 5.--Correlation coefficients indicating the relationship between the snow course water equivalent on given dates and March through July funoff volume at Tollgate Weir (10-year data).

Snow Course Ident. Number	Snow Water Equivalent March 1	Snow Water Equivalent March 15	Maximum Snow Water Equivalent
144062	.924	.906	.947
155054	.901	.905	.727
163020	.920	.923	.982
163098	.921	.910	.987
167007	.829	.690	.799
174026	.913	.934	.983
176007	.925	.896	.942

Table 6.--Statistics from pattern search optimization. March 1 model: accumulated precipitation at site 176X07 to March 1 and snow water equivalent on March 1 at 6 snow courses. March 15 model: accumulated precipitation at sites 176X07 and 163X20 to March 15 and snow water equivalent on March 15 at 6 snow courses. Maximum snow course water equivalent model: the maximum snow course water equivalent at 7 snow courses. (10-year data, 1966-1975.)

	Snow Water Equivalent March 1	Snow Water Equivalent March 15	Maximum Snow Water Equivalent
correlation coefficient	.96135	.9683	.9808
standard deviation	2.3037	2.0903	1.6335
coefficient of variance	.2728	.2475	.1934
standard error of estimate	1.1519	1.0452	.8167
round converged	32	31	5
times model was evaluated	409	414	78

Table 7.--Pattern search for optimum of objective function table of statistics; model results based on 9-year data (1966-74) from seven snow courses.

	Snow Water Equivalent March 1	Snow Water Equivalent March 15	Maximum Snow Water Equivalent
correlation coefficient	.9530	.9649	.9895
standard deviation	3.3617	2.9127	1.6044
coefficient of variance	.4197	.3636	.2003
standard error of estimate	1.1206	.9709	.5348
round converged	36	15	33
times model was evaluated	522	206	406

Table 8.--Pattern search for optimum of objective function table of statistics; model results based on 10-year data (1966-75) from seven snow courses for given dates.

	Snow Water Equivalent March 1	Snow Water Equivalent March 15	Maximum Snow Water Equivalent
correlation coefficient	.9285	.9476	.9908
standard deviation	3.1065	2.6722	1.1304
coefficient of variance	.3679	.3164	.1339
standard error of estimate	1.3893	1.1950	.5652
round converged	10	35	78
times model was evaluated	148	473	1091

Table 9.--Pattern search for optimum of objective function table of statistics; model results based on 11-year data (1966-76) from seven snow courses for given dates.

	Snow Water Equivalent March 1	Snow Water Equivalent March 15	Maximum Snow Water Equivalent
correlation coefficient	.9271	.9479	.9894
standard deviation	2.5604	2.1755	.9934
coefficient of variance	.3031	.2575	.1176
standard error of estimate	1.4782	1.2560	.5735
round converged	10	41	47
times model was evaluated	149	541	666

APPENDIX III

PRINCIPAL PROJECT ACCOMPLISHMENTS

1. *VEGETATION*

Hydrologic Characteristics of the 1977 Drought Documented. A summary report was prepared documenting the hydrologic effects on the Reynolds Creek Experimental Watershed of the 1977 water year drought. The severe drought conditions during the fall and winter (October 1976 to April 1977), of only 31 percent of the average precipitation, resulted in the smallest runoff amounts since records started in 1962. Groundwater well data showed a steady groundwater decline since 1969 with a very rapid decline during 1977. Soil water was below average during the spring, but was at or above average after the above average May and June precipitation. Forage yields were very low at the low elevations due to small amounts of early spring precipitation. However, at the high elevations, the forage yield was very good because of the above average amounts of precipitation during May and June. [This was also a principal accomplishment in Section 2, Runoff, and Section 3, Erosion and Sediment.]

Plant Material Study Establishes Those Best Adapted to Particular Soil, Elevation, and Precipitation Zones. The most suitable species of grasses and broadleaf plants for revegetating areas in the Intermountain Northwest have been determined from plant materials studies conducted on the Reynolds Creek Experimental Watershed. The tests were made on sites having a wide range of annual precipitation and were conducted during a period of wide variation in temperatures and precipitation. The recommendations take into account adaptability as well as uniformity of stand and production.

Survival and Species Composition Data Being Collected from a Rest-Rotation Grazing System. A 4-year rest-rotation system has been initiated on the Boise Front in Idaho. The study of this system will note any influence cattle and deer have on maintaining satisfactory stands of native grasses and will monitor the growth of browse plants under cattle and deer use. The study will provide action agencies needed information on the effectiveness of rest-rotation management and its impact on soil erosion. Information on summer and winter use of rangelands similar to the Boise Front is important to ranchers, range management specialists, and wild game managers.

Sagebrush Kill, an Anomaly of the 1977 Drought. A survey of sagebrush areas on Reynolds Creek has indicated an unprecedented kill of sagebrush. Areas of generally deep snow cover, essentially bare in the drought year, corresponds to kill areas. The interaction of snow cover and soil water is being documented.

2. RUNOFF

Stochastic Rainfall-Runoff Simulation Procedure Developed. A stochastic rainfall-runoff simulation procedure was used to determine how weather modification programs would affect the summer (May through September) runoff regime of western South Dakota rangeland watersheds. The study indicated a precipitation increase of 25.4 mm would increase runoff 8 to 10%, depending on watershed soil characteristics. The study also showed a 10% decrease in precipitation would decrease runoff about 20%. This indicates that significant decreases of runoff can result from small rainfall decreases.

Green and Ampt Infiltration Equation Parameters Determined. Sprinkling infiltrometer tests conducted on the Reynolds Creek Watershed were utilized to estimate the Green and Ampt infiltration equation parameters. The parameter estimation procedure, a fitting technique, was modified to account for the initial time lapse before the soil surface became saturated. This is a characteristic of sprinkling-type infiltrometers. The equation models measured infiltration rates quite well.

3. EROSION AND SEDIMENT

Major Sources of Rangeland Sediment Identified. Rangeland vegetation and slope data were utilized to compute soil loss from hillslopes, roads and streambanks. Soil loss from bare streambanks would be nearly 50 times greater and improved roads about 5 times greater than grazed hillslopes. Rangeland erosion control programs should concentrate on these major soil loss areas.

Erosion and Sediment Yield Documented for the Greatest Thunderstorm of Record. Hillside rill erosion from a rangeland watershed was measured as 15.7 to 35.8 tonnes per ha. The calculated USLE rainfall-runoff factor (R) was about 50 at the storm center, nearly 2.5 times the normal yearly factor at this site. The maximum suspended sediment concentrated exceeded 100,000 mg/l. Some stream channels were scoured to bedrock. Small area storms cause significant streamflow water quality degradation and off-site damage to roads.

Pollution Potential for Rangeland Livestock Systems Being Established. Bacterial indicators occur in highest concentration and over a longer time period under uncontrolled grazing practices where cattle are free to graze very large segments of open range. Under a rest-rotation system, bacterial and chemical indicators are being evaluated where the fenced allotments are used to control grazing for shorter time periods. A field study on the winter feeding cow-calf operation is now underway.

Magnitude of Total Dissolved Solids from Range and Irrigated Watersheds. During the 1973-1976 water years, an average of nearly 5424 tonnes of dissolved material per year was determined to have been removed from a 233 km^2 rangeland watershed with 810 ha of irrigated land. Sixty-five percent of the dissolved material originated from the irrigated lands, which comprises only 3 percent of the total area. During the 1977 drought year, only 1110 tonnes of dissolved material was removed from the total 233 km^2 with 46 percent originating from the irrigated fields. These results are significant because they show that irrigation runoff is a major source of water quality degradation on this rangeland watershed.

APPENDIX IV

ANNUAL WORK PLAN FOR FY 78

Location and Title of Study. The study will be conducted within the Reynolds Creek Experimental Watershed and adjacent satellite areas within the State of Idaho; the title of the study is "Reynolds Creek Experimental Watershed Study."

Work Plan for FY 78. The SEA-FR (formerly ARS), during the FY 1978 study period, will perform the following studies:

1. PRECIPITATION

   a. Utilizing a 15-year record from the 22-gage network on Reynolds Creek, a model will be developed for generating annual and monthly precipitation amounts. The influence of elevation and aspect will be incorporated into the model for transposing it to ungaged areas. Geographic areas will be defined for which the model may be applied.

   b. A network of four dual gages in the Boise Front study area has been established to represent elevation variability. Mean annual and seasonal precipitation and elevation relationships will be compared with the ARS data from Reynolds Creek.

2. VEGETATION

   a. On the Reynolds Creek Experimental Watershed, data collection will continue from grazed and nongrazed plots at nine sites. Observations will be made in each plot on changes in species composition and herbage yield at maximum cover. Also, soil surface factors, plot photographs, and trend plot data will be collected. Soil water data will be collected and processed biweekly during the grazing season at five study sites under both grazed and nongrazed practices. Soil water depletion models will be tested with these data. Herbage yield data through 1977 will be correlated with watershed factors, including precipitation, soil moisture, temperature, elevations, and aspect for six sites. Survival, persistence, and vigor of various species

will be determined at the three nursery sites and a report will be prepared presenting recommendations of species for seeding of areas represented by the three elevation-soil sites.

b. On the Boise Front study area, data will be collected at four sites on three pastures in the rest-rotation system on changes in nonbrowse species composition, cover percentages, seedling establishment, and vigor. Comparison data will be collected from nonuse areas. Eight browse study sites will be utilized to investigate vigor and use by deer and cattle. Soil water data will be collected biweekly at four sites for characterizing soil water storage and depletion. Soil surface factors will be determined at four study sites.

3. RUNOFF

a. On the Reynolds Creek Experimental Watershed, runoff rates and amounts will be collected and analyzed for two microwatersheds, three source watersheds, three tributary watersheds, and two main stem watersheds. Watershed models will be developed and tested for predicting water yield and runoff rates. An investigation of the correlation between mean annual and monthly runoff and precipitation for two watersheds will be made. Soil frost data will be collected for runoff modeling during rain and snowmelt events.

b. On the Boise Front study area, two streamflow gaging sites have been established, with two additional sites to be completed this year. High and low elevation, rest-rotation pastures are represented in these gaged watersheds. At two of the precipitation sites, weather stations have been established for collection of temperature, relative humidity, evaporation, and wind data. At all rain gage sites frost data will be collected. Comparisons will be made of Reynolds Creek runoff data with the Boise Front runoff data.

4. EROSION AND SEDIMENT

a. On the Reynolds Creek Experimental Watershed, sediment yield data will be collected from two microwatersheds, one source watershed, two tributary and two main stem sites. Bedload transport will be determined at six sites with sediment catchments or Helley-Smith samplers. Relationship of measured sediment transport to storm and channel factors for rainfall and snowmelt events will be studied. Sediment grain-size characteristics will be determined for selected runoff stations. Erosion and sediment yield data will be utilized to adapt and test prediction equations, such as the Modified Universal Soil Loss Equation.

b. On the Boise Front area, suspended and bedload material will be sampled on an event basis at four watershed sites. Sediment yield will be measured by establishing soil erosion sites on representative gullies, poorly vegetated hillslopes, and predominant range sites. Data will be collected to determine the factors of the Universal Soil Loss Equation. Actual soil losses will be measured from topographic surveys made after erosive storm events. If details can be arranged, an ARS rainulator will be used to evaluate the USLE C and K parameters.

5. WATER QUALITY

a. On the Reynolds Creek Experimental Watershed, bacteria determinations, DO, BOD, COD, and conductivity will be sampled at eight sites and complete chemical determinations at two sites on a regular schedule. Both the multiple tube and membrane filter methods will be used to determine bacterial concentrations associated with suspended sediment during major runoff events. Results will permit the separation of free coliform bacteria from those adsorbed on suspended sediment during runoff. Soil biological activity will be investigated to determine background coliform counts and survival of fecal coliforms on rangeland, following removal of cattle at the end of the grazing season. Information will be developed on sources of bacteria in streamflow under different soil, vegetative, climatic, and management conditions. Aquatic insect investigations will be conducted if the watershed is sprayed for grasshoppers and pesticide concentrations in the water will be determined. Rangeland management practices will be recommended that are consistent with State water quality standards. An initial study will be made of available water quality models that might apply to Reynolds Creek data. The basis of selection will be a model that may be used with limited data to produce reasonable results.

b. On the Boise Front study area, water quality samples will be collected at six sites. Initial efforts will be to develop baseline water quality information, which represents the rest-rotation grazing system. Comparisons will be made with water quality data from grazing practices represented on the Reynolds Creek Watersheds.